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ARS-BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

INTERIM REPORT NO. 4

Cooperative Agreement No. 14-11-0001-4162(N)

For Period January 1, 1973, to December 31, 1973

(NOTE: Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.)

MARCH 1974

TO

Denver Service Center
Bureau of Land Management
U. S. Department of the Interior
Denver, Colorado

FROM

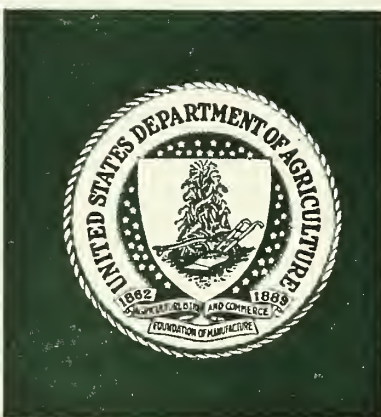
Northwest Watershed Research Center
Western Region
Agricultural Research Service
U. S. Department of Agriculture
Boise, Idaho

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INTRODUCTION

Cooperative watershed research between the Agricultural Research Service, U. S. Department of Agriculture, and the Bureau of Land Management, U. S. Department of the Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1961, which is a part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results from January 1 through December 31, 1973, as outlined in the work plan for F.Y. 1974. The report also describes the proposed activities and changes in objectives for consideration in the F.Y. 1975 work plan.

Significant changes in personnel at the Northwest Watershed Research Center were the addition of Dr. Clayton Hanson, Agricultural Engineer, to the professional staff, and the permanent appointment of several technicians to the support staff, formerly on temporary or part time appointments. These actions will provide greater competence in rangeland evapotranspiration studies and greater stability to the staff.

The Reynolds Creek Watershed is included within an area in southwest Idaho, which has been classified as needing management attention immediately. The poor condition of much of the area is a result of past abuse by livestock and wildlife, compounded by steep topography, erosive soils, and occasional severe storms. At present, proper grazing management is probably the key to range improvement in the area. However, recreational and other uses may cause different abuses and problems which must be controlled.

The major objectives of the research on the Reynolds Creek Watershed are to provide meaningful data for guidance in planning and implementing a range management and improvement program and to formulate procedures and models for predicting the effects of management and land-use changes on forage production, water yield, soil erosion, and related resources.

During the past year, rest-rotation grazing management plans were drafted and discussed by BLM personnel, ranchers, and the Watershed Staff; however, the ARS research plans on the Reynolds Creek Watershed were not changed. Logging on private land was closely observed for evidence of soil erosion, but erosive storm events did not occur.

Data collection for the 5-year study on the Rabbit Creek Watersheds was completed September 30, 1973, and instruments were removed soon thereafter. The final report on this study will be submitted about June 30, 1974, after analyses and data interpretations are complete.

Data collection, processing, and analysis continued according to the F.Y. 1974 work plan and details of progress and accomplishments are described in each section of the report. Further information is contained in Northwest Watershed Research Center Annual Reports for 1972 and prior years and in Interim Report Nos. 1, 2, and 3 of ARS-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 14-11-0001-4162(N).

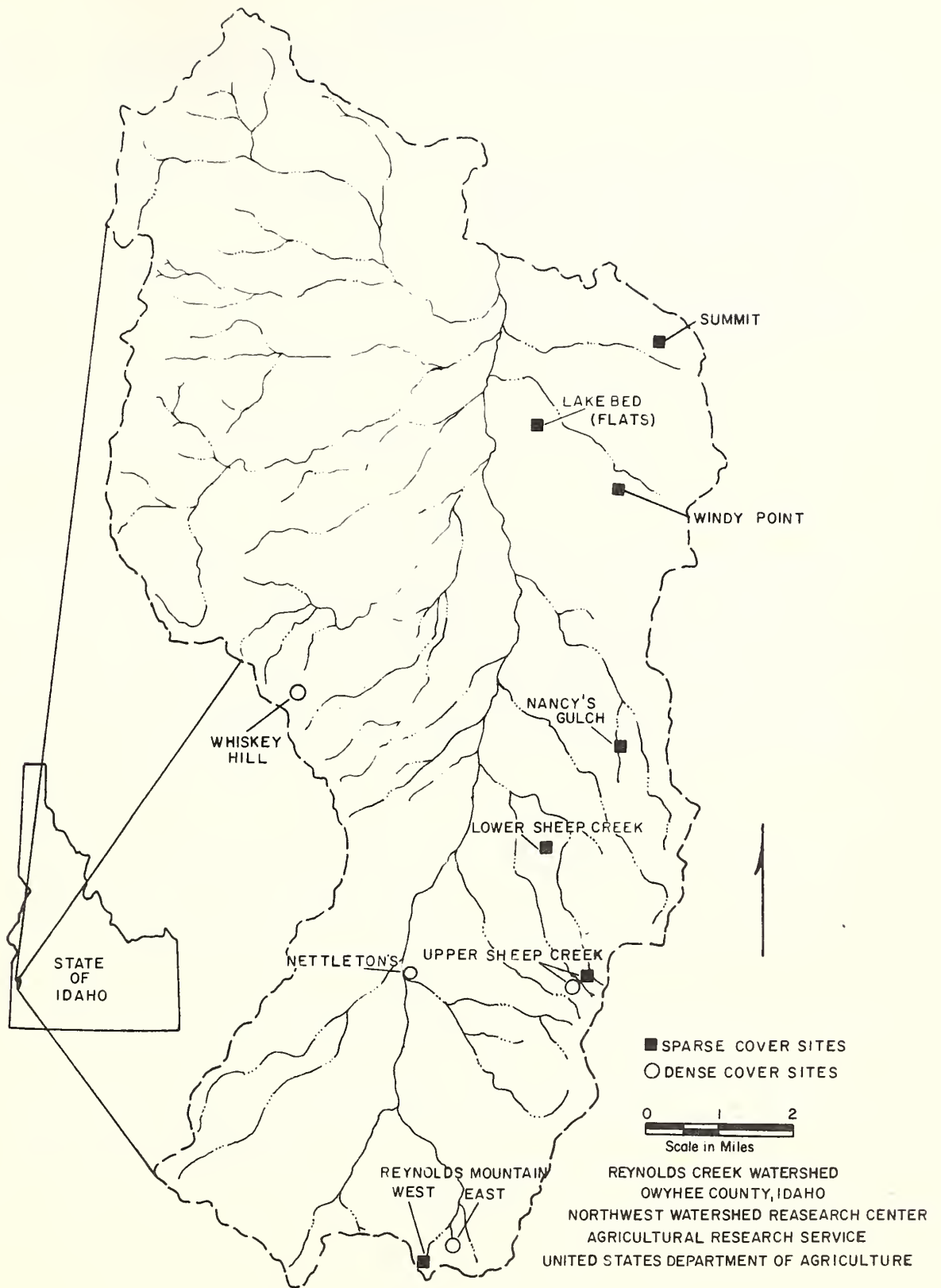


Figure 1. Location of experimental sites.

PRECIPITATION

Title: Precipitation characteristics of a northern, mountainous semiarid watershed.

Personnel Involved:

J. F. Zuzel, Hydrol. Tech.

Supervise data collections and conduct special analyses requiring the use of a computer.

W. J. Rawls, Hydrologist

Supervise data reduction and conduct special analyses requiring the use of a computer.

Date of Initiation: June 1961

Expected Termination Date: Continuing

INTRODUCTION

No dense, recording rain gage network existed in the Northwest prior to establishment of the Northwest Watershed Research Center. Such a network is necessary to delineate thunderstorms and storm variability. National Weather Service data collection stations are generally located in or near the main cities. Since these are generally along the main stems of major streams or in valleys, a sampling of precipitation on the range watershed areas is not available from their records. Also, there are too few rain gages capable of recording intensities or even individual storm data.

Objectives:

1. To develop methods for evaluating precipitation rates and amounts for watersheds of different sizes.
2. To determine seasonal distribution of precipitation with respect to amounts, character, and areal extent.
3. To develop depth-duration-frequency and depth-area-duration relationships for the Reynolds Creek Experimental Watershed.
4. To establish general precipitation-elevation-aspect-slope- relationships from precipitation data obtained in the Reynolds Creek Experimental Watershed.

PROGRESS

Precipitation data collection was continued from the gage network in the Reynolds Creek Watershed, comprised of 49 dual-gage sites (98 gages), and from the Rabbit Creek network, comprised of 5 dual-gage sites (10 gages). The Rabbit Creek network was dismantled in October 1973. Frequency analysis and stochastic models were investigated as tools for describing temporal and spatial variations of precipitation. Using the dual-gage model, computer programs were developed to convert shielded and unshielded precipitation data to actual precipitation. In addition, a precipitation intensity program has been developed, and all precipitation data for 1968-1973 were converted to actual precipitation. The sensitivity of the dual-gage model coefficient was tested over its expected range and found to be relatively insensitive, producing error ranges of 10 percent or less. A comparison of rain gage data from gages equipped with free-swinging and constrained windshields indicates that gage catches are essentially the same for both types.

The results of a comparison of annual unshielded gage catch and actual precipitation computed from the dual-gage model and regression equations are shown in Figure 1. The need for correcting unshielded gage catches is immediately apparent. For example, the unshielded gage catches of water years 1972 and 1973 are almost identical, yet a difference of 33 (13 inches) cm of water exists in the computed precipitation values. This difference is attributable to less severe winds in 1973 to which the dual gage model is sensitive.

A comparison of annual precipitation, computed from the dual-gage model and from a regression model, is shown in Figure 2. Regression model input consists of shielded gage values only, while dual-gage model input requires both shielded and unshielded gage values. The magnitude of the differences in precipitation suggests that a regression equation applied to either a free-swinging or constrained shield rain gage can produce precipitation values as reliable as the dual-gage model on an annual and seasonal basis. However, development of the simplified procedure was dependent on data from the dual-gage network.

SIGNIFICANT FINDINGS

The dual-gage precipitation model coefficient, when varied over its expected range, has proven to be relatively insensitive and produces error ranges of 10 percent or less.

No difference in rain gage catch was found between rain gages equipped with constrained windshields and rain gages equipped with free-swinging windshields.

A correction factor, derived from regression analysis and applied to either a free-swinging or constrained shield rain gage, can produce precipitation values as reliable as the dual-gage precipitation model on an annual and seasonal basis. Since water balance and hydrologic model studies require an accurate precipitation input, computed actual precipitation can now more confidently be used as input to these models.

WORK PLAN FOR FY 1975

Frequency analysis and stochastic models will be used to determine and simulate temporal variations of precipitation. Studies of precipitation intensities will be initiated.

REPORTS AND PUBLICATIONS

Zuzel, J. F. 1973

ABSTRACT - Estimation of rain gage catch deficiency. Pub. Trans. NW Reg. Meeting, Amer. Geophys. Union, Missoula, MT, 55(2): 78.

Zuzel, J. F. 1973

Precipitation studies at Reynolds Creek. Pres. ARS-SCS Western Hydrol. Workshop. Boise, ID.

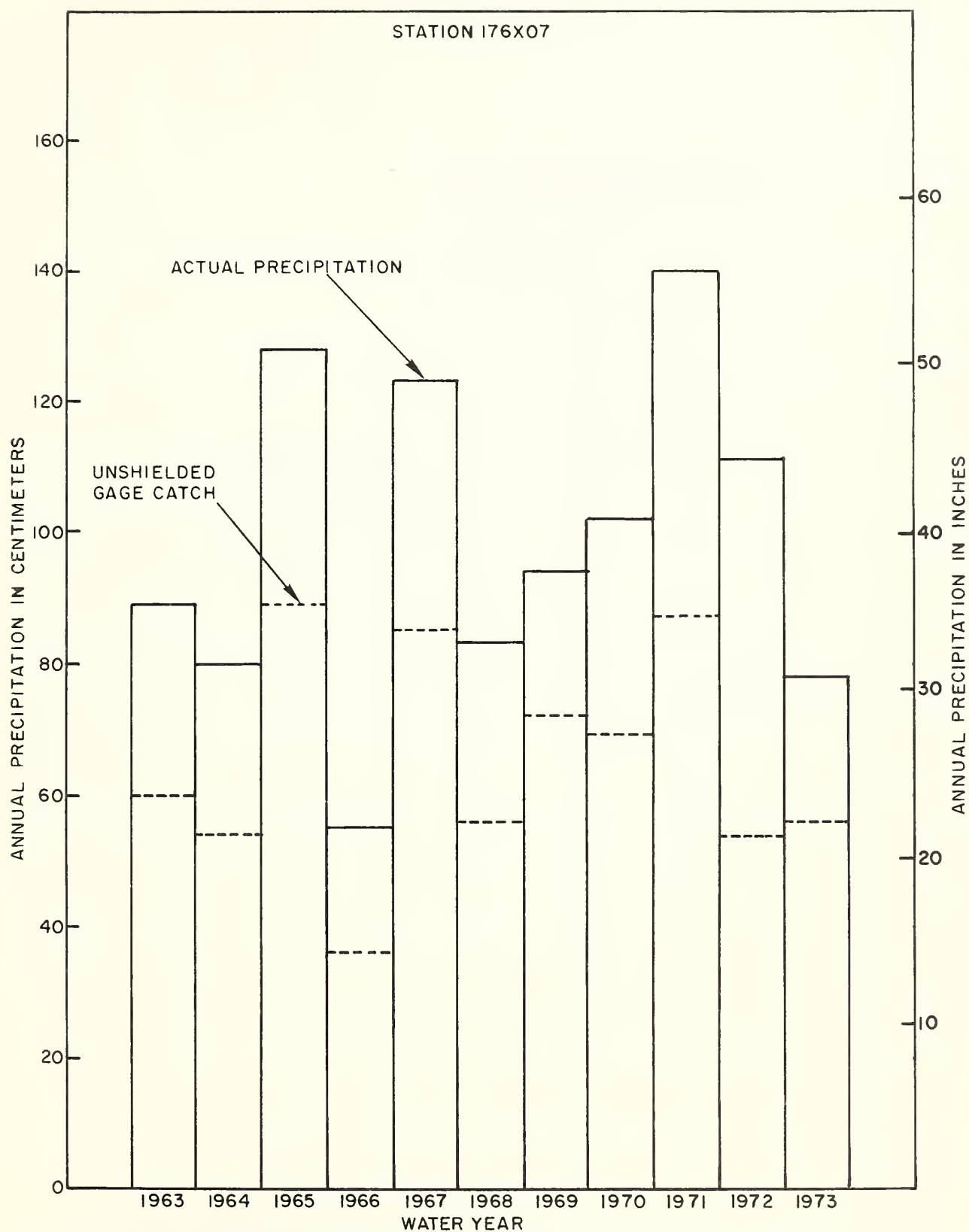


Figure 1. Unshielded gage precipitation catch and computed actual precipitation, Station 176X07, Elevation 6600 ft.

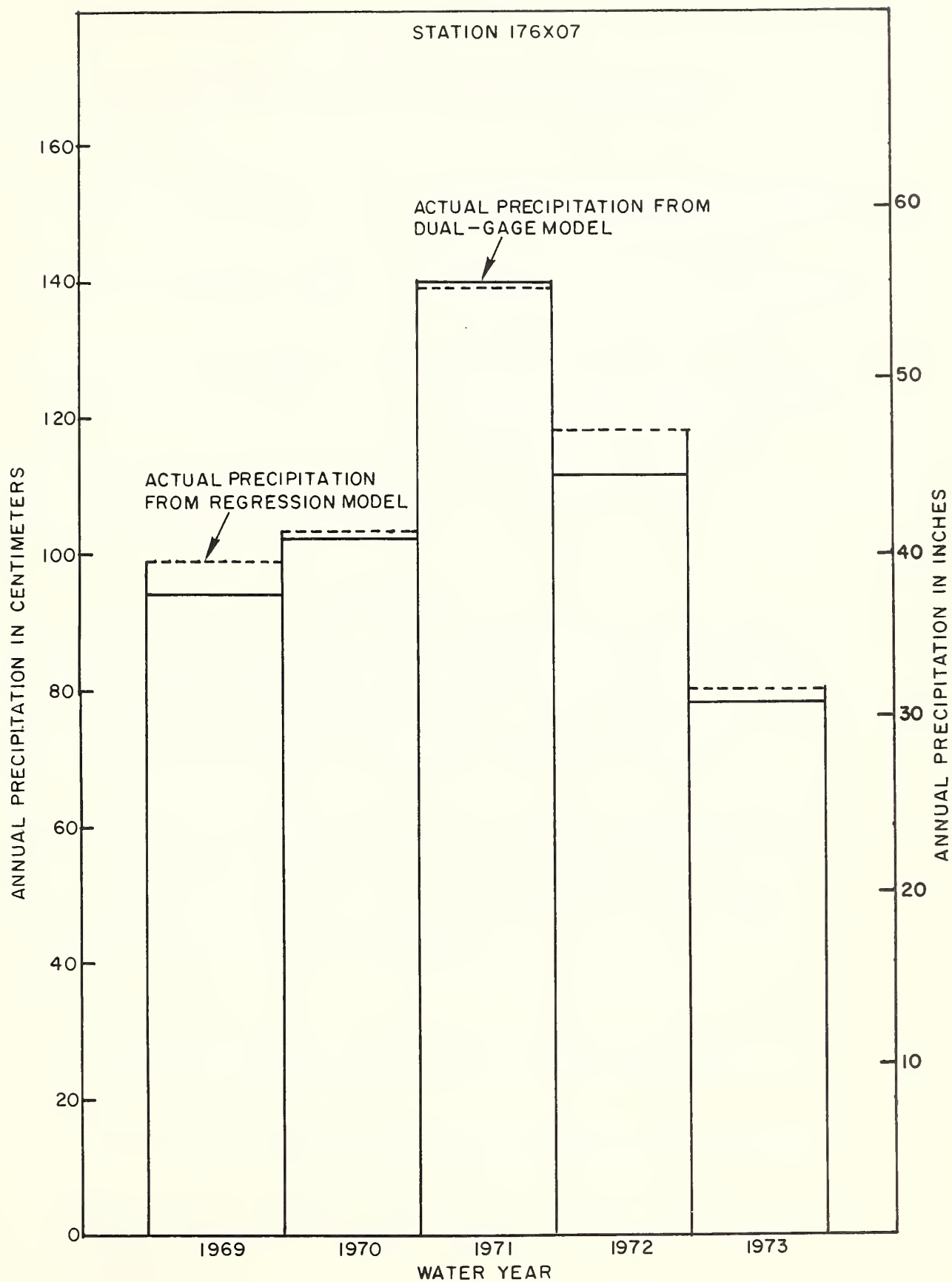


Figure 2. Comparisons of water year precipitation, computed by the dual-gage model and by the regression model.

SNOW

Title: Snow accumulation, snow redistribution, and snowmelt.

Personnel Involved:

<u>L. M. Cox</u> , Hydrologist	Supervise the planning, designing, execution, analyzing, and reporting of proposed experiments.
J. F. Zuzel, Hydrol. Tech.	Assist in the planning, designing, execution, analyzing, and reporting of proposed experiments.
W. J. Rawls, Hydrologist	Assist in the planning, designing, execution, analyzing, and reporting of proposed experiments.

Date of Initiation: 1961

Expected Termination Date: Continuing

INTRODUCTION

A substantial proportion of the runoff from the western rangelands has its origin in rapid melting snow. To improve the quantity or timing of flow from snow-fed streams by manipulation of vegetation or by other practices requires that the behavior of snow be well understood. There has been little research on the behavior of snow in shrub areas anywhere--and almost none in the sagebrush areas of the Northwest.

Destructive late winter and spring floods in the Northwest frequently originate from rapid melting snow at low elevations, characteristic of the sagebrush zone. Although there is little likelihood of modifying snowmelt rates enough to alleviate this threat, knowledge about the behavior of snow in the sagebrush zone will be helpful in devising better warning and forecasting techniques that may reduce the danger to life and property from snowmelt floods.

Objectives:

1. To determine the physical and meteorological factors contributing to nonuniformity of snow accumulation in shrub-covered study basins on mountainous terrain.
2. To determine the influence of the controlling physical and meteorological factors on snowmelt from the above areas.
3. To improve snowmelt prediction techniques by evaluating the energy exchange process of the snow surface under different snow cover conditions.

4. To study the oasis effect of isolated, late-lying snowdrifts to minimize evaporsublimation losses and to maximize and prolong water yield from snowmelt.

PROGRESS

Snowmelt evaluation studies showed that vapor pressure, net radiation, and wind explained 78 percent of the variance associated with the snowmelt process. Melt predictions, based on vapor pressure, net radiation, and wind, were improved by 14 percent as compared to using temperature measurements alone.

A long-term water supply forecast model, using parameter optimization techniques on snow course data, was developed and successfully tested on three basins in southwest Idaho.

Preliminary analysis of photogrammetric snow measurements indicates that snow depths in the study area can be determined with a standard error of 0.6 ft. Snow density zoning methods were not critical in estimating the total quantity of water stored in a small watershed snowpack.

SIGNIFICANT FINDINGS

Snowmelt predictions, based on vapor pressure, net radiation, and wind, improved melt predictions by 14 percent, compared with predictions using temperature measurements alone.

A long-term water supply forecast model has improved forecast accuracy by 5 percent when compared to the models now used by the Snow Survey Section of SCS.

WORK PLAN FOR FY 1975

The energy exchange process will be evaluated by comparing data from meteorological parameters, independent measurements of energy balance components, and melt collectors. The data were obtained during FY 1974 on areas of continuous snow cover and isolated late-season snowdrifts.

Short-term streamflow forecasting techniques will be further refined, using melt data from several types of snowmelt collectors, snow courses, and energy balance measurements.

The accuracy of predictions of the areal distribution of snow and snow-water content on a watershed will be tested, and 3 years of photogrammetric and 10 years of snow course data will be statistically evaluated.

REPORTS AND PUBLICATIONS

- Cox, L. M. 1973
ABSTRACT - A new device for evaluating the energy exchange processes that contribute to the ablation of a snowpack.
20th Ann. Meet. Pacific NW Reg. Sec., Amer. Geophys. Union. 55(2):77.
- Cox, L. M., and J. F. Zuzel 1973
Forecasting runoff from universal surface gage snowmelt measurements. Jour. of Soil and Water Cons. 28(3): 131-134
- Norris, S. L., and L. M. Cox 1974
Research plus action. Soil Cons. 39(6).
- Cox, L. M. 1973
Snow hydrology studies at the Northwest Watershed Research Center. Pres. ARS-SCS West. Hydrol. Workshop, Aug. 20-24, Boise, ID.
- Rawls, W. J., and J. R. Zuzel 1973
Computer modeling studies. Pres. ARS-SCS West. Hydrol. Workshop Aug. 20-24, Boise, ID.
- Cox, L. M.
A device for evaluating the net water vapor exchange between snow and air. (Being reviewed for pub. in Water Resources Res.)
- Zuzel, J. F., and L. M. Cox
A statistical analysis of the relative importance of meteorological variables in the snowmelt process. (Being reviewed for pub. in Water Resources Res.)
- Zuzel, J. F., D. C. Robertson, and W. J. Rawls
Optimization of long-term streamflow forecast model coefficients. (Being reviewed for pub. in Jour. of Soil and Water Cons.)

VEGETATION AND SOIL MOISTURE

Title: Evaluation of cover production, herbage yield, and soil conditions for different levels of vegetation management.

Personnel Involved:

<u>G. A. Schumaker</u> , Soil Scientist	Plan, design, and coordinate research activities and prepare reports.
W. J. Rawls, Hydrologist	Prepare computer programs for analysis of vegetation data.
C. L. Hanson, Agr. Engin.	Perform computer analysis relative to soil moisture data and assist in summarizing field data.
D. L. Coon, Hydrol. Tech.	Responsible for various aspects of data collection and field observations including soil moisture measurement and calibration; compile research outline data.

Date of Initiation: May 1971

Expected Termination Date: Continuing

INTRODUCTION

Quantitative data on herbage yield from rangelands under different levels of management are needed to guide land managers in coordinated multiple use of the range. These needs require more discerning information on how vegetation and soils respond to imposed treatments, including controlled grazing. Information is also needed with regard to methods of increasing cover and to the rate of recovery of native range following intensive grazing practices.

Objectives:

1. To determine the effects of grazing management and treatments on yield of herbage, cover production, soil moisture regimes, and soil surface conditions at selected sites.
2. To study changes in plant density and plant composition as a result of grazing management and treatments.

PROGRESS

Vegetation

Vegetation studies for 1973 were concentrated on six of the nine study sites at the Reynolds Creek Experimental Watershed. Cover changes occur slowly on the other three sites that have sparse vegetation; therefore, clippings and basal area data were not obtained. Descriptive information for all study sites is given in Table 1. Locations of the study sites are shown on Figure 1 of the Introduction section of this report.

Herbage yields: The double sampling technique was used once again this year in determining plot yields. This method involved two steps: (1) three sample areas, which previously had been estimated, were clipped and weighed in the field by two technicians; (2) herbage weights were then estimated on ten other random sample areas. This procedure increased the sample size with only a minimum of extra time.

Total herbage and non-sage yields from the brush treatments at the Nancy site, where the annual precipitation is about 11 inches, are shown on Figure 1. Some small sagebrush plants were evident on the brush-removed treatment, which accounts for the 200 lb/ac difference between the total herbage and non-sage yields. These plants were in the seedling stage at the time of clearing in 1971. The herbaceous sagebrush on the sprayed treatment contributed about 150 lb/ac, where about 80 percent kill was accomplished by spraying in 1971. A statistical analysis showed that the yield of grasses and forbs on the brush-controlled treatments was significantly greater than on the other treatments at the 5 percent level. Competition for moisture and shading by the brush limited the yields of grass and forbs where the brush was controlled. It is speculated that a new stand of grass was slow to establish at this site following spraying in 1971.

Yields in 1973 from the Upper Sheep Creek study are shown on Figure 2. Total herbage yields on all three treatments within the enclosure were near 2,000 lb/ac. There was a very small amount of Artemesia tridentata on the sprayed and brush-removed areas after five growing seasons following treatment. About 1,000 lb/ac more grasses and forbs were produced on the sprayed and the brush-removed treatments than were produced without brush treatment. This difference was statistically significant at the 5 percent level.

Total yields and non-sage yields at the Reynolds Mountain site are shown on Figure 3. Grass and forb yields on the brush removed area were significantly greater at the 5 percent level than on the other treatments. It is apparent that more than 2 years response time is needed for the understory grasses and forbs to increase following spray treatment. Sagebrush on this site was sprayed in 1971.

The Whiskey Hill site includes a spray treatment but not a brush-removed treatment. Total yields in 1973 were 503, 836, and 800 lb/ac on the sprayed, untreated, and grazed treatments, respectively. Only one growing season has passed since the sagebrush was sprayed, and total yields on the sprayed treatment have not yet equaled or surpassed the yields on either the grazed or untreated sites. Non-brush yields were 493, 449, and 302 lb/ac on the sprayed, untreated, and grazed treatments, respectively. More grasses and non-brush forbs were produced on the sprayed treatment than on either of the other two treatments. The increase was statistically significant at the 10 percent level.

The Nettleton site has an excellent cover of grasses and forbs with only a small percentage of brush species present. Before 1971 the site was under private management and was grazed late in the season. Since the site was developed for experimental purposes, the grazed portion of the study has been subjected to intensive grazing. Total yields in 1973 were 1,133 lb/ac from the exclosure and 1,208 lb/ac from the grazed portions of the study. Although vegetation on the Nettleton study site appears uniform, yields from individual sample points ranged from 500 to 1,500 lb/ac in the exclosure.

The Nettleton site was subjected to intensive grazing by 12 cattle during the 21-day period from June 11 to 25, 1973. The 6.33 acres provided .53 acres per animal for grazing. From the clippings, the forage production was estimated to be 1200 lb/ac and should have been nearly sufficient for animal requirements during the grazing period.

Species composition: Vegetation data from the 700 line transect points, taken on each of the brush treatments at the four brush treatment sites, were divided into four groups: grasses, lupine, other forbs, and shrubs. The study at Upper Sheep Creek was started in 1969. The 1973 information for this site is of interest for comparison of different treatments. The percent of various vegetation species groups is shown on Figure 4; horizontal lines provide a graphic comparison of response to different treatments. The small percentages of brush species on either the brush-removed or sprayed treatments show the effectiveness of brush control. The percent of lupine was not reduced by spray application, but other forbs were controlled by spraying.

Comparisons of similar groups of vegetation at the Reynolds Mountain site are shown on Figure 5. Lupine made up a large portion of the vegetation on the brush-removed treatment. This was probably due to the mechanical nature of the grubbing operation, which resulted in better seed placement. At present, groups of vegetation are not different on either the grazed area or the untreated portion of the exclosure.

Similar data are given in Table 2 for the Nancy and Whiskey Hill sites. No distinct trends are apparent at this time other than the effect of the treatments on brush species.

Vegetative cover: Line transects for depicting cover were run in 1973 on all but three of the study sites. The percentage for each cover class at each of the sites is given in Table 3. In general, the grazed treatments have less vegetative cover and more bare ground than the untreated portion of the enclosure.

The sprayed treatment at Reynolds Mountain has a comparatively low amount of vegetation and more bare ground. Continued measurements will determine changes in cover makeup due to treatment.

Trend plots: A series of photographs were obtained on the trend plots at all study sites to depict changes in vegetation under the different treatments. These photographs have been taken annually from the beginning of the study.

Soils

Erosion condition: Observations for soil Surface Factor determinations were taken on the different treatments at each of the study sites in 1973. Very little change was noted from 1972. All sites were given the erosion condition class of "stable" except a designation of "slight" for the sparse vegetation sites at Upper Sheep Creek and Lower Sheep Creek.

Comparison of bulk densities: Bulk density measurements were taken at Whiskey Hill following grazing to determine differences between the enclosure where cattle did not have access and the adjacent area open to grazing. Average bulk densities from ten sampling points were 1.20 g/cc on the sprayed area of the enclosure and 1.30 g/cc on the grazed area. Statistical analysis showed that these means were significantly different at the 5 percent level. The difference is attributed mainly to the effect of cattle trampling. There appears to be a sufficient increase in grass to cause increased root permeation in the soil at the time of measurement, which partly accounts for the decreased bulk density.

Soil water: Soil water measurements were taken regularly during the growing season, beginning when the soil water was near its maximum and ending when it was depleted. In comparison with the other treatments, brush removal showed some effect on water loss at the three sites: Nancy, Upper Sheep Creek, and Reynolds Mountain (Figures 6, 7, and 8). There was very little difference in water loss between the sprayed and untreated plots. The cover offered by the dead sagebrush on the sprayed treatment probably acted much the same as the live sagebrush in providing shade to the soil surface and reducing air movement, thus keeping surface soil moisture loss to a minimum.

At Reynolds Mountain a comparison was made of water removed on the three different brush treatments from the 4-foot zone to determine water use by sagebrush late in the season. There were no apparent differences in water use between treatments. August and September rain at the Reynolds site may have provided necessary moisture for growth rather than the sagebrush drawing moisture from the 4-foot zone.

Daily evapotranspiration rates were determined for the period of June 5 through July 31 at Upper Sheep Creek, including precipitation during this period. Similar data was summarized for an 84-day period beginning May 9 at Reynolds Mountain. At both locations the daily loss due to evapotranspiration was .09 inches of water per day. This value agrees very favorably with values reported by Rawls (see publication list at end of this section) where estimates from data collected over a period of years showed .10 in/day as evapotranspiration at Reynolds Mountain and .07 in/day at Lower Sheep Creek.

SIGNIFICANT FINDINGS

At Upper Sheep Creek and Reynolds Mountain, the amount of non-sage herbage was significantly greater on the sprayed and brush-removed treatments than where the sagebrush had been treated.

The percent of lupine was much greater where sagebrush was removed by grubbing in 1971 at Reynolds Mountain.

Significant differences in soil bulk densities, measured on grazed and ungrazed sites at Whiskey Hill, were attributed mainly to the effect of cattle traffic during grazing.

Moisture loss from the soil was different where Artemesia tridentata remained than where the brush was completely removed, leaving only understory grasses and forbs.

WORK PLAN FOR FY 1975

Measurement of changes in species composition, cover, herbage yield, and soil conditions for different vegetative treatments will be continued. Emphasis will be given to measurement of herbage yield, notation of cover change, and measurement of changes in plant vigor at the different sites.

Yield and vegetative cover data collected in the field will be related to treatments on sites representing different ecological zones.

Water use under different types of brush control will be investigated by measurement of neutron soil moisture through the growing season at five study sites.

Methods will be developed for sampling the surface inches of soil on sites where gravelly soils do not lend themselves to ordinary methods of bulk density measurement.

The measurement of change in crown height of sod due to frost heaving will be continued at two sites.

The percent of bare ground at the end of the grazing season will be measured to determine forage utilization and erosion potential.

The effect of cattle traffic on soil compaction and the effect of increased grass cover on bulk density will be studied.

REPORTS AND PUBLICATIONS

Rawls, W. J., et al. 1973

Soil moisture trends on sagebrush rangelands. Jour. of Soil and Water Conserv. 28(6): 270-272.

TABLE 1.--Tabulation of site information

SITE	ELEVATION (feet)	SLOPE ^{2/} (percent)	ASPECT OF SLOPE	PRECIPITATION ^{2/} (inches)		SOIL SERIES ^{2/}	VEGETATIVE ^{2/} COVER (percent)	SCS HYDROLOGIC CLASSIFICATION
				SPARSE VEGETATION SITES				
Flats	4000	5	North	9		Nannyton loam	<25	B
Nancy's Gulch	4600	8	Northeast	13		Glasgow loam	<25	C
Lower Sheep Creek	5400	16	Northwest	16		Searla gravelly loam	<25	B
Upper Sheep Creek	6100	25	Southwest	22 ^{3/}		Gabica cobbly gravelly loam	<25	D
Reynolds Mountain West	6850	5	Southwest	32 ^{3/}		Bullrey gravelly loam	<25	B
DENSE VEGETATION SITES								
1/ Nettleton's	5000	25	West	21		Reywat-Bakeoven rocky very stony loam	>50	D
	Reynolds Mountain East	6800	6	Northwest	32 ^{4/}	Bullrey gravelly loam	>50	B
Upper Sheep Creek	6100	33	Northeast	22 ^{4/}		Harmehl and Demast loam	>50	C
Whiskey Hill	5550	15	East	17		Takeuchi rocky coarse sandy loam	>50	B

^{1/} Good grass cover site on soil developed from basalt.^{2/} Based on 1961 survey.^{3/} Snow removed by wind.^{4/} Snow deposition zone.

TABLE 2.--Vegetative composition at Whiskey Hill^{1/} and Nancy study sites expressed as percent of total vegetation.

Whiskey Hill

Vegetation	Sprayed %	Untreated %	Grazed %
Grasses	57.4	19.5	14.5
Lupine	1.3	2.1	6.8
Other Forbs	25.3	18.8	11.5
Shrubs ^{2/}	16.9	59.6	67.2

Nancy

Vegetation	Brush Removed	Sprayed %	Untreated %	Grazed %
Grasses	60.2	53.9	38.6	31.9
Lupine	0	0	0	0
Other Forbs	34.5	20.3	25.3	34.6
Shrubs ^{2/}	5.3	25.8	36.1	33.5

^{1/} There was no brush removal treatment at the Whiskey Hill site.

^{2/} Including Artemesia tridentata

TABLE 3.--1973 cover measurements taken at study sites.

Location	Treatment	Vegetation %	Litter %	Rock %	Bare Ground %
Nancy	Brush Removed	45.6	15.9	9.6	30.2
	Sprayed	42.9	19.7	13.7	23.8
	Untreated	50.4	12.6	11.6	25.4
	Grazed	39.1	11.0	12.2	37.7
Upper Sheep Creek	Brush Removed	68.3	13.7	0.5	17.0
	Sprayed	53.7	36.1	0.6	9.6
	Untreated	72.0	20.3	0.5	7.2
	Grazed	57.1	30.7	0.0	12.2
Reynolds Mountain	Brush Removed	54.7	25.9	7.4	12.0
	Sprayed	30.1	51.0	3.2	15.6
	Untreated	69.5	20.4	2.3	7.8
	Grazed	65.5	19.4	4.0	11.2
Whiskey Hill	Sprayed	32.5	40.8	0.6	26.2
	Untreated	58.0	18.8	0.0	22.7
	Grazed	50.8	23.0	0.9	25.0
Flats	Exclosure ^{1/}	57.2	8.0	4.7	30.5
	Grazed	47.7	8.4	6.6	37.1
Nettleton	Exclosure ^{1/}	52.3	26.0	5.0	16.8
	Grazed	31.7	31.0	3.9	33.4

^{1/} Not grazed

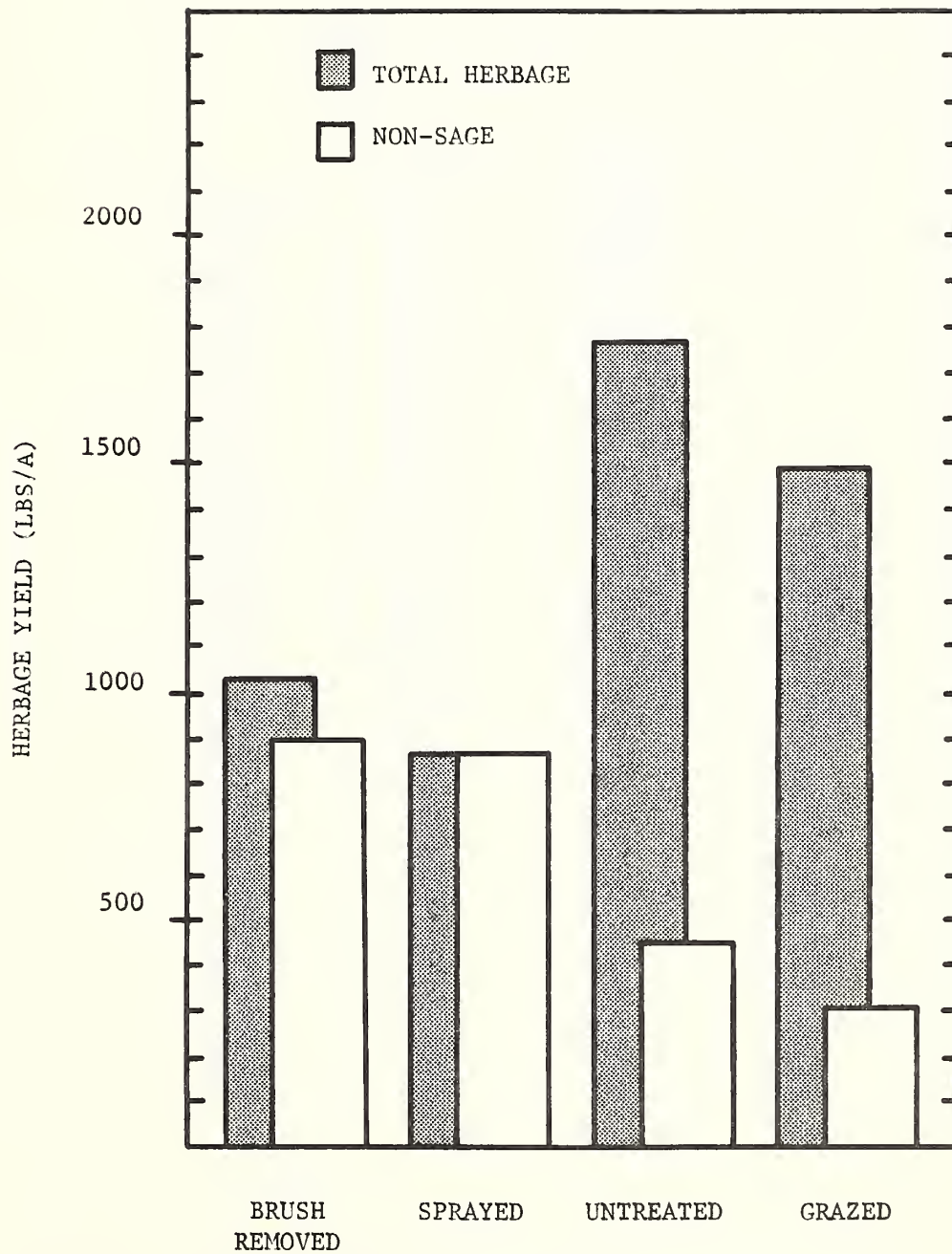


Figure 1. Total herbage yields and non-sage yields at the Nancy brush treatment site, 1973.

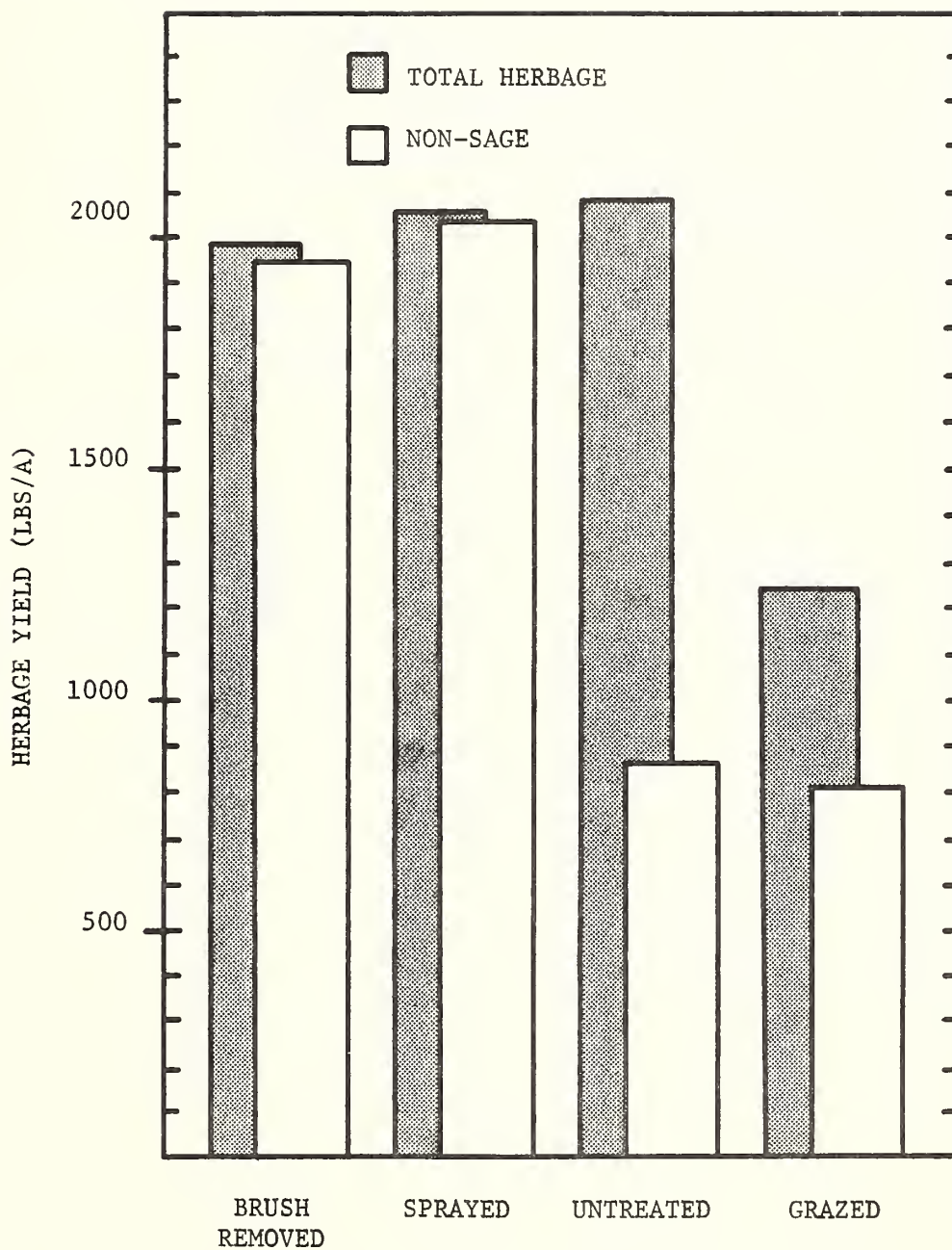


Figure 2. Total herbage yields and non-sage yields at the Upper Sheep Creek brush treatment site, 1973.

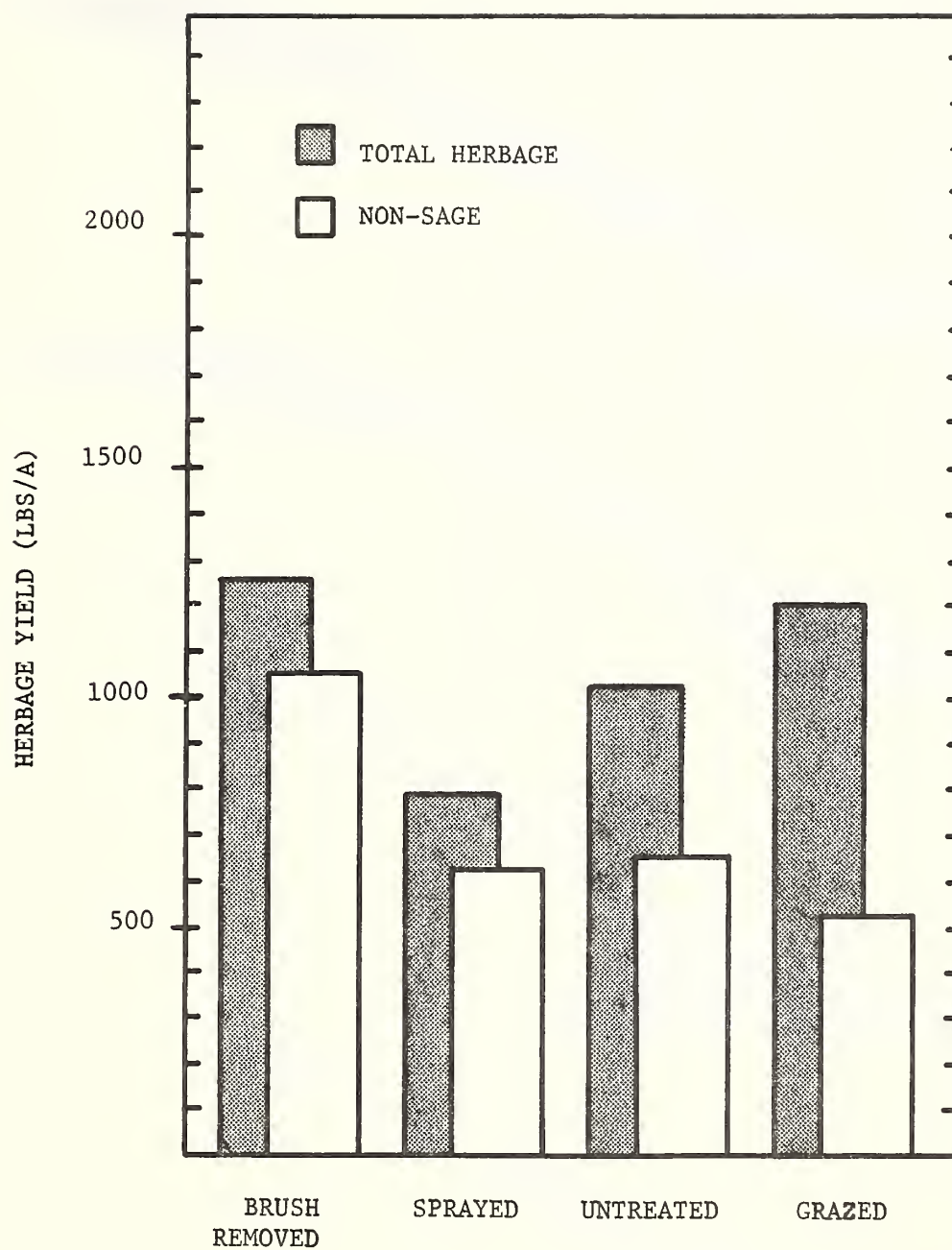


Figure 3. Total herbage yields and non-sage yields at the Reynolds Mountain brush treatment site, 1973.

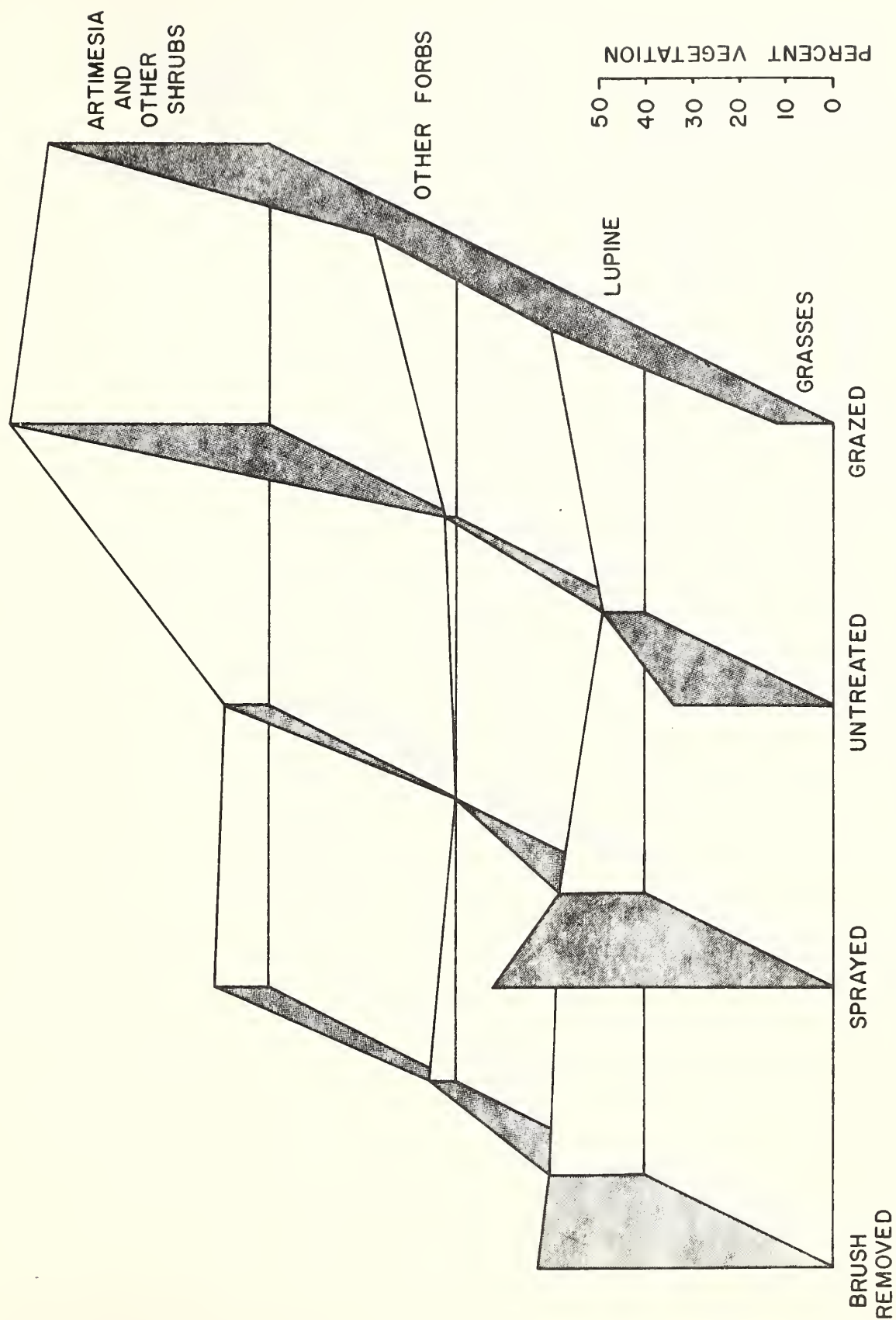


Figure 4. Percentage of different vegetation groups present under different types of brush treatment at Upper Sheep Creek, 1973.

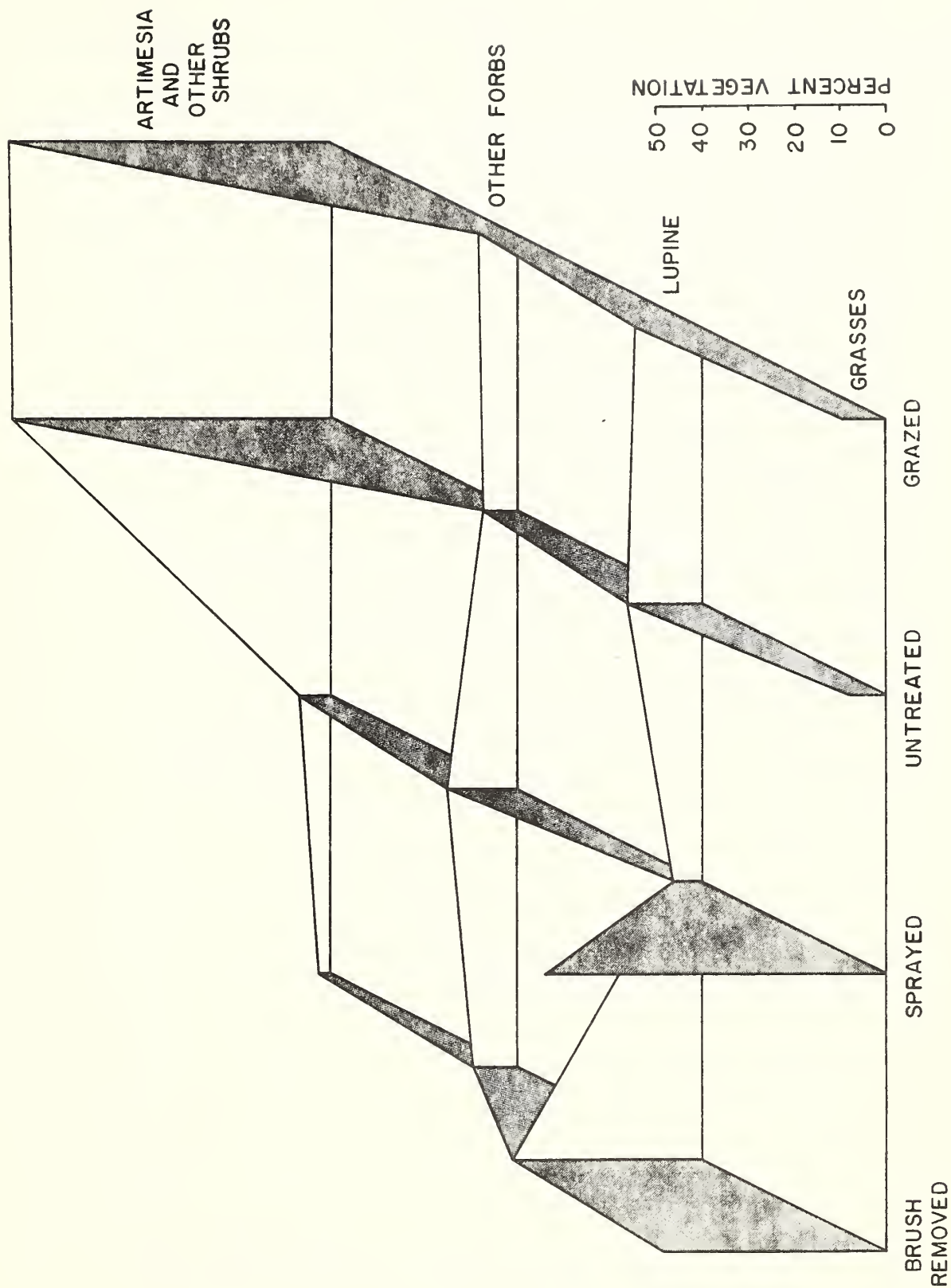


Figure 5. Percentage of different vegetation groups present under different types of brush treatment at Reynolds Mountain, 1973.

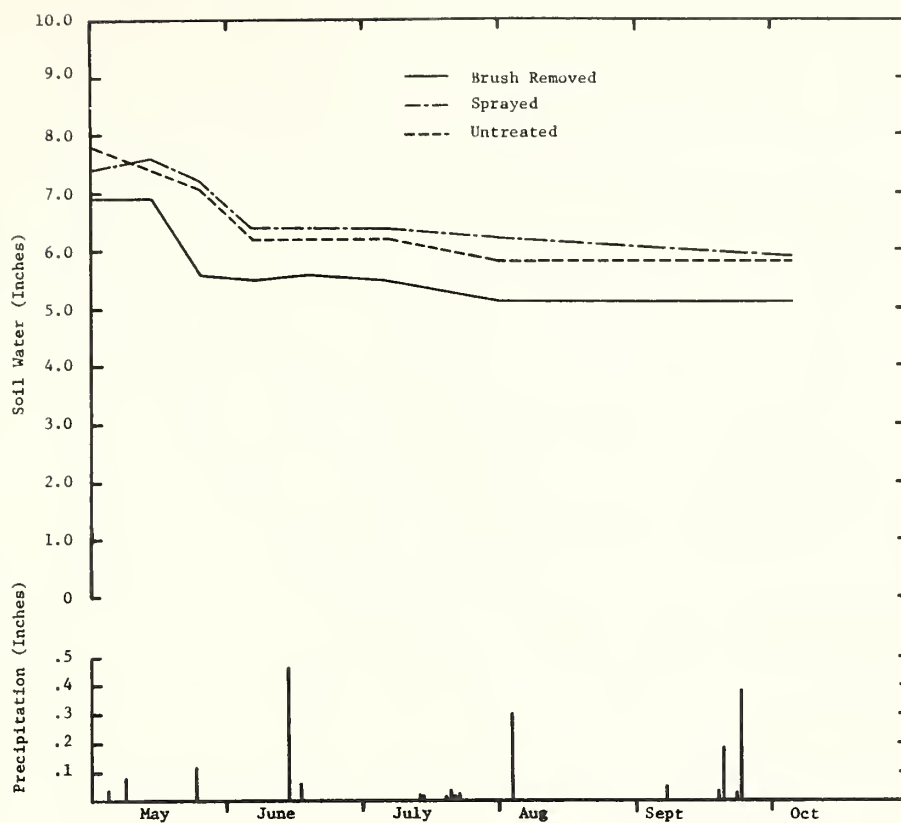


Figure 6. Soil water content for the 0- to 2-ft. depth at the Nancy site for different brush treatments and daily precipitation, 1973.

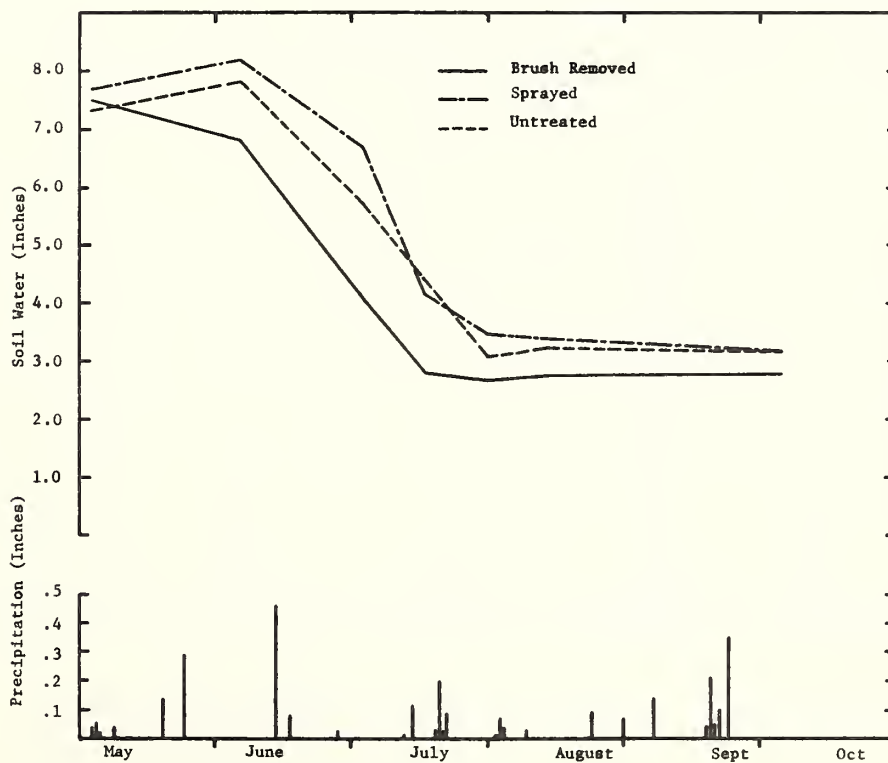


Figure 7. Soil water content for the 0- to 3-ft. depth during the growing season and daily precipitation at the Upper Sheep Creek site for three different brush treatments.

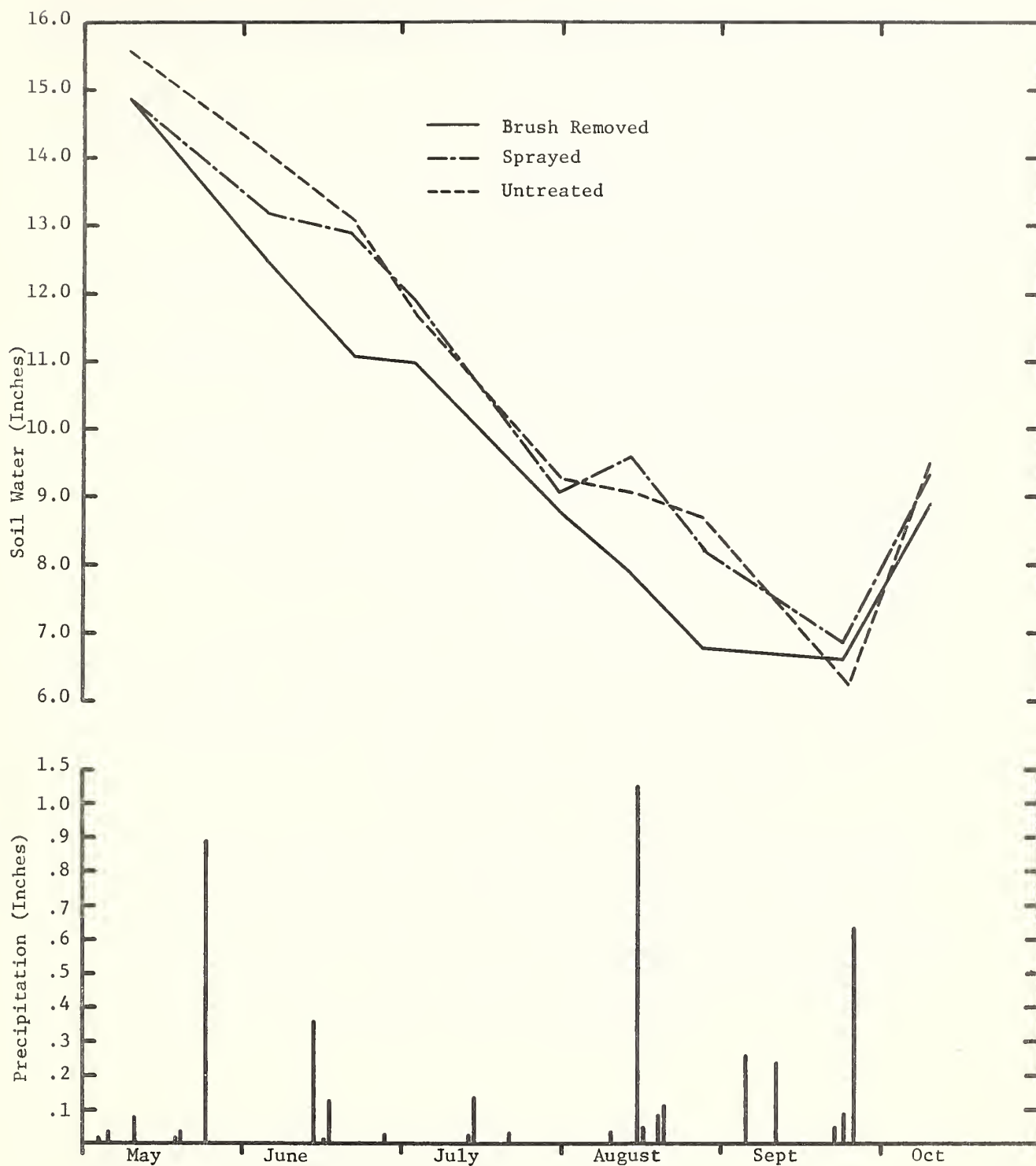


Figure 8. Soil water content for the 0- to 4-ft. depth during the growing season and daily precipitation at the Reynolds Mountain site for three different brush treatments.

INFILTRATION

Title: Developing, testing, and evaluating an analytical infiltration model

Personnel Involved:

<u>W. J. Rawls</u> (ARS-Boise)	Supervise field data collection; coordinate the research with the cooperators; perform any other analysis needed.
G. A. Schumaker (ARS-Boise)	Collect necessary soils and vegetation data
W. R. Hamon (ARS-Coshocton, Ohio)	Coordinate the 5-year technical bulletin on infiltration work performed at Boise
R. W. Jeppson (Utah State University)	Develop and field test analytical infiltration models
R. H. Brooks (Oregon State University)	Assess soil properties in laboratory and in the field; help establish field procedures; help develop and field test analytical infiltration models

Date of Initiation: February 1971

Expected Termination Date: Continuing

INTRODUCTION

Infiltration of water into soil profiles is probably the most critical hydrologic component in watershed management, overland flow prediction, sediment generation, natural and artificial ground-water recharge, and irrigation. More accurate information concerning the flow system resulting from infiltration is essential if agricultural lands are to be managed for optimum multiple use. The Northwest Watershed Research Center has been conducting an infiltration research program aimed at developing, testing, and evaluating analytical infiltration models.

Objectives:

1. To develop or adapt mathematical models in the form of partial differential equations to describe steady-state and transient one-dimensional and three-dimensional axisymmetric flow through partially saturated soils.

2. To use mathematical models to adjust for the lateral "spreading effect" of moisture movement from a circular rainfall simulator under various soil types and conditions.
3. To test and refine the mathematical models by comparing results with laboratory and field determinations of infiltration, and to establish the relative influence of the several interacting physical processes on infiltration.
4. To determine the saturation-pressure relationship (moisture characteristic) and saturated conductivity parameters by the use of parameter optimization in conjunction with the mathematical models and infiltration data.
5. To determine the potential quantity of water retainable by various soil-vegetation complexes independent of infiltration and different initial soil moisture levels.

Mathematical models of steady and transient one-dimensional and three-dimensional axisymmetric flow through partially saturated soils have been formulated by R. W. Jeppson of Utah State to satisfy objectives No. 1 and 2. The collection of the field data to satisfy objectives No. 3, 4, and 5 was performed in the summer of 1972. The field program was discussed in the Interim Report No. 3.

PROGRESS

The numerical infiltration model testing with the field data was expanded beyond the models developed by Jeppson at Utah State University, to include those proposed by Rogowski (ARS-Pennsylvania State University), Brooks (Oregon State University), and Smith (ARS-Tucson, Arizona). The results from this expanded testing program have not been completed; however, preliminary results indicate that all the models yield satisfactory results. Testing of a number of the well known empirical infiltration models has also begun. After the testing of all the models has been completed, they will be evaluated according to their usefulness in evaluating the effects of land management changes.

Laboratory capillary pressure-saturation analysis of soil cores taken during the field program were completed. Comparison of insitu capillary pressure-saturation data and laboratory capillary pressure-saturation data indicated a good correspondence at the surface or near the surface (0 to 2 inches); however, at lower depths the correspondence was very poor. This poor correspondence was due to sampling procedures and sampling conditions.

The numerical models indicate that the surface layer has the most predominant effect upon the hydraulic behavior of the soil. Thus, hydraulic classification of the surface soils may be all that is necessary to describe the infiltration characteristics of the soil.

Attempts at fitting a number of empirical equations describing the capillary pressure-saturation relationships under drainage and imbibition conditions indicate that the imbibition and drainage functions are different. Most of the present equations were developed for the drainage conditions. Our research indicated a more suitable function for imbibition was:

$$S_e = \frac{.85b}{(P_c/P_b)^\lambda + b}$$

where,

S_e = effective saturation

P_c = capillary pressure

P_b = bubbling pressure

λ = pore size distribution

b = constant

The unknowns in this function are b , P_b and λ and attempts are being made relating these to soil properties.

A procedure for determining the hydraulic properties of natural soils insitu was developed and can be summarized as follows:

1. Soil density and capillary pressure data were obtained simultaneously at designated depths with an infiltrometer, gamma probe, and tensiometer equipment through the time that water was applied at a constant rate less than the ultimate infiltration capacity of the soil.
2. Bulk densities of soil samples taken from the site were determined to convert the soil density measurements to saturation values.
3. Numerical solutions simulating the field tests and based on the field saturation-capillary pressure data from steps 1 and 2 were obtained to define the unsaturated hydraulic properties of the soil.

4. The optimal dimensionless application rate was determined by matching the numerical solutions to the saturation-time curve of the field data. The saturated hydraulic conductivity was then computed.
5. Upon achieving satisfactory agreement in Step No. 4, the mathematical model could be used in sensitivity analyses to study such effects as different application rates, initial conditions, etc., on moisture spreading, rate of movement and location of wetting front, and other factors associated with the infiltration process.

Four chapters of the technical report on the infiltration work at Boise were completed. Work is continuing on the last two chapters.

SIGNIFICANT FINDINGS

A procedure for determining the hydraulic properties of soils insitu was developed. It was found that present equations representing the capillary pressure-saturation relationship during drainage are not applicable for imbibition. Also, a comparison of insitu capillary pressure-saturation data and laboratory capillary pressure-saturation data indicated a good correspondence at the surface or just below the surface; however, this was not true at lower depths.

WORK PLAN FOR F.Y. 1975

The relative influence of the physical processes on infiltration will be studied using optimization, and various theoretical and empirical infiltration models will be field verified. A technical bulletin summarizing all the infiltration work at Boise will be completed.

REPORTS AND PUBLICATIONS

- Brooks, Royal H., Paul J. Leclercq, Richard R. Tebbs, and Walter J. Rawls 1974
Axisymmetric infiltration. Water Resources Res. Inst. Report 22, Oregon State Univ., Corvallis, OR. 61 pp.
- Rawls, W. J. 1973
Infiltration studies pres. at ARS-SCS Western Hydrol. Workshop, August 20-24, Boise, ID.
- Will, Gregory R. 1973
Rainfall simulator. Masters Thesis, Oregon State Univ., 70 pp.

EVAPOTRANSPIRATION

Title: Natural evaporation from sagebrush rangelands, alfalfa, and stock ponds in a semiarid environment.

Personnel Involved:

C. L. Hanson, Agr. Engin.

Plan programs and procedures; design and construct facilities for evaporation studies. Perform analyses and summarize results.

G. H. Belt, Assoc. Prof.
Watershed Mangt.
University of Idaho

Analyze and report on experimental data.

Date of Initiation: November 1968

Expected Termination Date: Continuing

INTRODUCTION

A complete understanding of the evaporative process is essential when developing predictive relationships for the evapotranspiration component in definable soil vegetation complexes under a particular level of management. The Northwest Watershed Research Center, in cooperation with the Department of Forestry, University of Idaho, has been conducting evapotranspiration studies designed for measuring and predicting evapotranspiration under sparse vegetative cover and unsaturated surfaces.

Objectives:

1. To determine the evaporative loss of water from sagebrush rangelands, irrigated alfalfa, and stock ponds, while observing pertinent meteorological parameters and the soil moisture status.
2. To develop, for predictive purposes, relationships for associating the evaporative loss with meteorological parameters, type and degree of surface cover, soil moisture, and potential evaporative demand.

PROGRESS

Profile micrometeorological data obtained over irrigated alfalfa and dryland sites with sparse covers of sagebrush and greasewood were utilized to determine the Bowen ratio and the surface and aerodynamic resistances. The surface resistance was found to be proportional to the Bowen ratio. The proportionality coefficient, a bulk surface resistance parameter, was dependent upon the availability of water for the evaporation process. This resistance representation of the Bowen ratio was combined with the aerodynamic and energy budget equations to obtain an energy balance-resistance model; an iterative procedure was used to compute evapotranspiration and near-surface temperature. The data required consists of air temperature and humidity, windspeed, surface roughness, and an estimate of the bulk surface resistance parameter. This parameter was incorporated into a combination equation, and computed values of evapotranspiration were compared with those obtained by the energy balance-resistance model. Development of this model is continuing at the University of Idaho.

A somewhat different approach from the previous work is now being used to describe watershed evapotranspiration. The first reason for this change in direction is because of the change in personnel; and the second being an attempt to develop an evapotranspiration model that can be directly included in a watershed hydrologic model.

A review of the literature indicates that a model of the following form can be developed for the Reynolds Creek Watershed.

The model is expressed as:

$$ET = ET_p K_p K_{sw} + EV$$

in which

ET = total evapotranspiration (inches/day)

ET_p = potential evapotranspiration (inches/day)

K_p = plant coefficient

K_{sw} = coefficient of limiting soil-water

EV = evaporation from the soil and plants (inches/day)

Four lysimeters, two at the Lower Sheep Creek and two at the Reynolds Mountain experimental sites, were calibrated and the necessary instruments obtained so that these lysimeters will be in operation during the 1974 growing season. The information from these lysimeters will

be used to obtain the constants for the above evapotranspiration model. Data from the neutron soil-water measuring program will also be used to improve the model and to determine if the constants in the evapotranspiration model will have to be different for various areas on the watershed.

SIGNIFICANT FINDINGS

An energy balance-resistance model for computing evapotranspiration was developed by using profile micrometeorological data obtained over irrigated alfalfa and sagebrush rangeland. Data required for the model consists of air temperature and humidity, windspeed, surface roughness, and an estimate of the effective resistance of the surface.

WORK PLAN FOR FY 1975

The goal is to develop a basic evapotranspiration model for rangeland watersheds, based on the equation

$$ET = ET_p \frac{K_p}{K_{sw}} + EV,$$

using lysimeter data and supporting information from the neutron soil-water measuring program. This model has been successfully used to describe evapotranspiration from rangeland in South Dakota. It will most likely be necessary to obtain additional information from the lysimeters so that the constants in the model can be tested. The model will then be used in a watershed hydrologic model.

A manuscript describing the bulk energy balance-resistance evapotranspiration model will be completed.

REPORTS AND PUBLICATIONS

Hamon, W. R., and G. H. Belt. ABSTRACT. Energy balance-resistance model for computing evapotranspiration. Trans., American Geophys. Union, 54(4) H59: 270, 1973.

Hanson, C. L. Model for predicting evapotranspiration from native rangelands in the northern Great Plains. Ph.D Dissertation, Utah State Univ., Logan, UT, 116 pp, 1973.

WATER QUALITY

Title: Water quality characteristics of the hydrologic flow regime of the Reynolds Creek Experimental Watershed.

Personnel Involved:

<u>G. R. Stephenson</u> , Geologist	Responsible for coordinating activities with cooperators. Design collection network and responsible for project completion.
J. F. Zuzel, Hydrol. Tech.	Responsible for statistical analysis of data and shares the responsibility for aquatic sampling.
C. M. Rountree, Biol. Tech.	Responsible for collection of water samples, aquatic samples, and laboratory analyses.

Date of Initiation: October 1972

Expected Termination Date: Continuing

INTRODUCTION

In recent years, because of the increased concern for the quality of our environment, many agricultural practices have come under close scrutiny as potential sources of air and water pollution.

Several agricultural practices are known to have contributed to pollution of surface and ground-water resources. Feedlot operations under certain conditions do contribute to increasing nitrate content of adjacent surface and ground water. Heavy grazing on open range usually compacts the soil, reduces infiltration, and seriously reduces the vegetative cover, increasing runoff. Increased turbidity and contribution of sediment and nutrients to the streams are often the result. Irrigation usually contributes heavily to total salt and nitrate-nitrogen content downstream. However, not all agricultural operations are detrimental.

Information is needed on the water quality characteristics of rangeland watersheds under natural conditions and various land management practices. The Reynolds Creek Experimental Watershed offers an excellent opportunity to study water quality characteristics related to several of the above-mentioned problems. No commercial fertilizers or pesticides have been used on the watershed. Herbicides were used infrequently for sagebrush control, but not since 1965.

With the present distribution of hydrologic networks throughout the watershed, sampling of both surface and subsurface flow for water quality analyses can easily be accomplished. The water quality constituents can be related to the hydrology of the system, particularly the properties of the water, the distribution, and the circulation.

The BLM has expressed need for more information on water quality changes influenced by various land management practices. As more rangeland is being used for recreation, this information becomes more important.

Objectives:

To determine water quality characteristics of the hydrologic flow regime of the Reynolds Creek Experimental Watershed as related to

1. Concentrations of cattle on local areas of rangeland and quasi-feedlot conditions,
2. Irrigation return flow, and
3. Natural soil and geologic conditions.

PROGRESS

During the past year, seven samplings for water quality have been made at nine sites on Reynolds Creek. Approximately 25 chemical analyses were completed for each sample, providing baseline data for determining water quality characteristics. The samples were also analyzed for total and fecal coliform counts.

Four samplings of aquatic invertebrates were made during the year at five sites on Reynolds Creek, ranging in elevations from 3600 to 5400 feet. Three samples were taken at each of the five sites using a Surber square-foot sampler. Samples were preserved in alcohol, sorted to order, and counted.

Because of the near drought conditions existing on Reynolds Creek throughout most of 1973, any conclusions reached from analysis of this data should be related only to unusually low flow conditions. The prospects for greater streamflow in 1975 are much improved. This should aid in observing quality variation under different climatic conditions.

Chemical analysis: Because of the quantity of data collected during the water year at all nine sites on Reynolds Creek, only two selected sites will be used here to illustrate the significant water quality variations that occurred. The Lower Reynolds site characterizes waters receiving irrigation return flows, and the Tollgate site characterizes streamflow from open rangeland, upstream from any irrigation return flow.

In comparing the dominant chemical constituents at the two sites (Figure 1), there is a marked increase in levels of concentration at the Lower Reynolds site during the irrigation season. Concentration levels at the Tollgate site remained relatively constant. The sodium adsorption ratio (SAR), an alkali hazard index computed using sodium, calcium, and magnesium concentrations, shows that the water at Lower Reynolds is not dominated by sodium and has a low alkali hazard, but that there is an increase in salinity during the irrigation season. This same relationship is evident when analyzing the electrical conductivity (EC) measurements. Other chemical constituents shown in Figure 1, though present in much lower concentrations, show much the same increase during the irrigation season.

Total phosphate (P), often used as an indicator of eutrophic conditions because of the solubility of the orthophosphates from applied fertilizers, does not follow the same variation trends in Figure 1, as do the other constituents. Phosphate ions characteristically are adsorbed to the suspended solids in streamflow and to channel sediments. This condition appears to be true in Reynolds Creek because the higher the percent of suspended solids the higher the concentration of total (P). Because no commercial fertilizers have been applied to range or croplands on the Reynolds Creek Watershed, the total phosphates are derived from natural sources and very little soluble orthophosphates are present.

From the above analyses, based upon a relatively dry year, the increase in chemical concentration progressing downstream on Reynolds Creek is caused by irrigation and very little change is related to grazing conditions on open range.

Coliform analysis: Coliform analyses of the water samples were not conclusive because counts vary considerably between sites and between sampling dates. However, it appears that average fecal coliform counts are higher at sites where there are concentrations of cattle (See Table 1). Further analyses of the coliform data show that an increase in both total and fecal counts occurs with a corresponding increase in flow. A need for an increase in the sampling network and sampling frequencies is evident.

TABLE 1.--Average fecal coliform counts for the Reynolds Creek sampling sites.

Reynolds Outlet	78	*Nettleton	166	Democrat	30
*Lower Reynolds	104	Tollgate	56	*Reynolds Mtn. Weir	181
Tyson	89	Dobson Creek	86	Reynolds Mtn. Spring	8

* These sites are subject to concentration of cattle.

Aquatic invertebrates: All aquatic samples were dominated by immature insecta with a scattering of leaches and snails, especially at the lower elevations. Total populations ranged from a high of over 1300 individuals per square foot at the outlet weir (3600 ft. msl) in October to 90 per square foot at the Tollgate Weir (4600 ft. msl) in July. Average sample composition was: Trichoptera 47%, Ephemeroptera 23%, Diptera 15%, Plecoptera 7%, and Coleoptera 6%. Invertebrate forms other than the insecta accounted for 2% of the average sample composition.

Although the data are quite limited, tentative inferences as to the spatial and temporal variations in total population can be made at this point. The results of a temporal and spatial analysis of the data, using elevation as the space defining variable and month of the year as the time defining variable, are given on Figure 2. Time and elevation trends are evident. Generally, total populations are highest at all stations in October and lowest in June. Since August totals are higher than in June, additional sampling should define the peak of this apparent cyclical change. Channel relationships being equal, the elevation to population relationship indicates that less dense populations will be found at increasingly higher elevations. Quantification of this relationship will also require additional sampling. An examination of Figure 2 suggests the possibility that the combination of a log transform of the space parameter and an autoregressive model, using the time parameter, could define and possibly predict the population response surface.

Ground water investigations: Geochemical investigations of multi-aquifer systems in basalt and lake sediments have provided data for selecting several chemical parameters for use in identifying the waters of two different aquifer systems. The relationship of sodium adsorption ratio to electrical conductivity was found to be the most significant. Differences in this relationship were used to classify the waters according to origin. Basaltic waters were found suitable in quality for most crops grown in this area; whereas, water from lake sediment aquifers was less suitable. Considerable variation in water quality exists where there is hydraulic continuity between the two aquifers.

SIGNIFICANT FINDINGS

Analysis of 1973 surface water data show that: (1) increases in chemical concentration of surface water in Reynolds Creek, such as increased salinity, are related to irrigation return flow and not to grazing conditions on open range, and (2) increases in total and fecal coliform counts are related to concentrations of cattle, but are still much below Public Health Standards.

Geochemical investigations of ground-water flow systems show that: (1) several chemical parameters may be used to identify waters of separate systems, and (2) water from the basaltic aquifer is much better in quality for irrigation than lake sediment water.

WORK PLAN FOR FY 1975

Additional sampling sites will be added to the present sampling network in areas where cattle concentrate during the grazing season on open range. These sites will be used to obtain better coliform information. Additional samples will be collected during high flow conditions when they occur.

The present sampling network will be monitored for both chemical and aquatic determinations.

We will continue to analyze the data as soon as possible after laboratory analyses are completed. No change in method of analyses, as outlined in the 1974 annual report, is contemplated.

Water quality data from ground water and surface water systems will be used in a comprehensive water quality model.

REPORTS AND PUBLICATIONS

None.

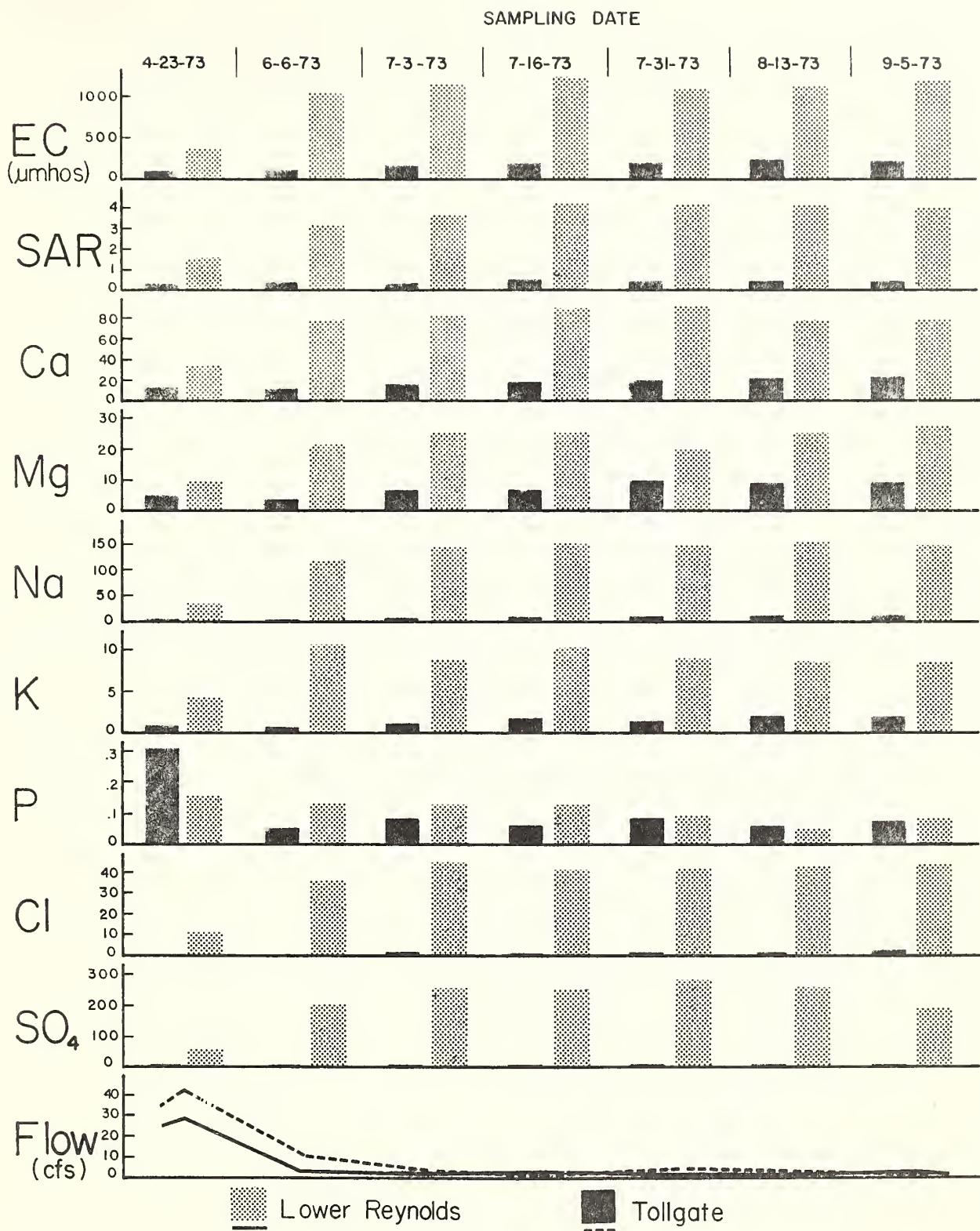


Figure 1. Major chemical constituents (mg/l) and channel flow at Tollgate and Lower Reynolds sites.

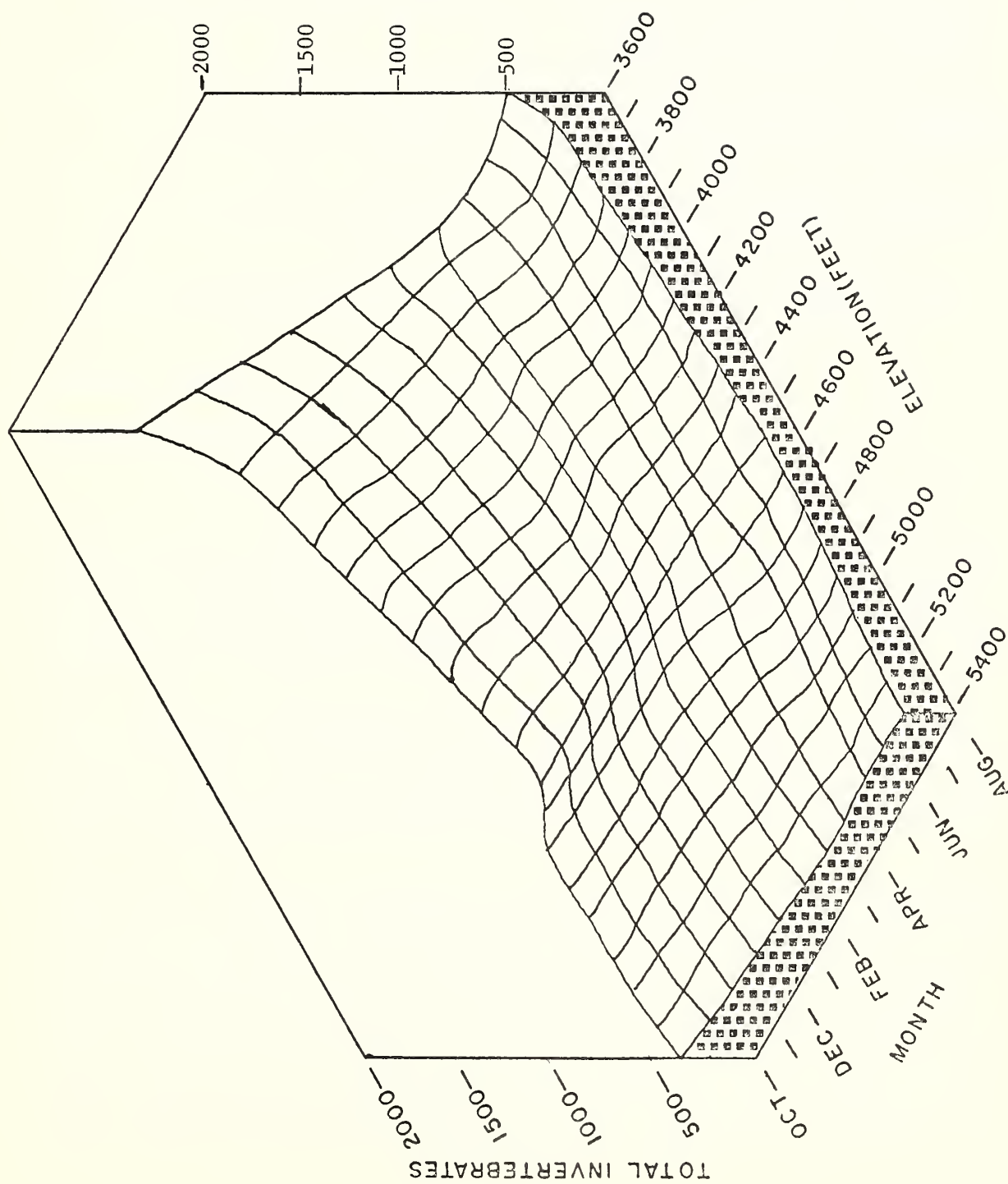


Figure 2. Elevation and month versus total invertebrates per square foot at Reynolds Creek

RUNOFF AND SEDIMENT

Title: Sediment yield from rangeland watersheds.

Personnel Involved:

<u>C. W. Johnson</u> , Supvy. Hydraul. Engin.	Plan programs and procedures; design and construct facilities for sediment studies; perform analyses and summarize results.
G. R. Stephenson, Geologist	Determine geologic and geomorphic parameters related to sediment yield.
C. L. Hanson, Agr. Engin.	Test various components in sediment models most applicable to rangelands.
R. L. Engleman, Hydrol. Tech.	Perform data compilation and assist in analyses.

Date of Initiation: September 1, 1969

Expected Termination Date: Continuing

INTRODUCTION

Information on sediment yield is almost entirely lacking for millions of acres of predominantly sagebrush rangeland under government land management and private ownership in the Northwestern United States. There is a growing concern for soil losses from intensively grazed rangelands, sediment damage to reservoirs, and erosion of stream channels.

Most rangeland watersheds in the Intermountain Northwest have large areas of relatively steep hillslope topography, and these areas need to be delineated for treatment to reduce erosion. Also, sediment yield information is needed for evaluating the benefits of watershed management and land treatment programs of the Bureau of Land Management and Soil Conservation Service.

Range sites found in the Reynolds Creek Experimental Watershed represent a large percentage of the rangeland in the Northwest, and studies of sediment yield are essential for developing sound management practices and planning appropriate multiple use of these lands. Good land management decisions require information on how vegetative changes, fencing, and land use alter the sediment yield potential of rangeland watersheds. The sources of these sediments need to be determined so that research data can be used to predict sediment yield for ungaged areas in terms of available information on soils, climate, physiography, and use. Research is also needed to adapt the Universal Erosion Equation to rangelands.

Objectives:

1. To determine the relationships between sediment yield and variables describing hydraulic and hydrologic factors and site and watershed characteristics that influence sediment yield.
2. To formulate a sediment yield prediction procedure for rangeland watersheds in the Northwest.

Suspended and bedload sediment yields from plots, channels, and watersheds are measured by pumping sediment samplers, splitting devices, catchments, and hand sampling. Plots, microwatersheds, and watersheds are located on various soil types in different precipitation zones. A wide range of slope length, slope area, aspect, and relief ratio is represented. Rainfall intensity and duration data are available from a network of precipitation gages, and snow data are available from snow courses, snow pillows, and other snow-measuring sites. Also, data on cover, topography, and soil factors, which influence erosion and sedimentation, are available through other investigations at the Northwest Watershed Research Center.

PROGRESS

Facilities and instrumentation for measuring runoff and sedimentation from six plots and two microwatersheds were completed in 1973. Descriptive data for the plot and microwatershed sites are contained in Table 1, and locations are shown on Figure 1 of the Introduction section of this report.

Precipitation at the Reynolds weather station during the 1973 water year was slightly above the 12-year average, as shown in Table 2. Monthly amounts were below or near normal except in April when the total was 3.22 inches, the greatest monthly amount reported anywhere in Idaho. This record April precipitation also produced the peak runoff rates during the 1973 water year. Flooding did not occur since the precipitation was partly snow and there was no frost in the soil. Consequently, sediment yields were low from most watersheds. Monthly runoff in 1973 and the 11-year averages are compared in Table 2. Generally, near-average precipitation produced only about 60 percent of the average runoff.

A study of winter storm and flood events on the Reynolds Creek Watershed shows that, during the 1962-72 period of record, most major floods occurred during December through March. Also, shorter-duration sedimentation records indicate that these events cause a large proportion of annual sediment yield on a water year basis. However, results of the study show the extreme variability in watershed areas that contribute runoff and sediment during a single event. During the winter of 1973, secondary peak runoff rates occurred in mid-January, but these peak rates were lower than usual and runoff-erosion plots contributed no measurable sediment.

Bedload samplers have been procured to complement the suspended sediment sampling program. This equipment will provide total sediment yield data at a few streamflow sites, especially during major flood events.

Processing and analysis of sediment data continued through 1973, and results will be submitted for publication in 1974.

SIGNIFICANT FINDINGS

The Reynolds Creek Experimental Watershed is well located to represent extensive rangeland areas in southwest Idaho and surrounding states to provide data on flood and sediment-producing events. Analyses of a few winter flood events have shown that runoff from portions of the 90-square-mile Reynolds Creek Watershed ranged from 0 to 0.8 inch. Similarly, measured suspended sediment concentrations ranged from 0 to 80,000 mg/l. The meteorologic, hydrologic, and hydraulic processes that cause runoff, erosion, and sediment movement are very complex and require extensive watershed data for analyses.

Runoff and sediment yield were very low in 1973 when compared with average water year amounts since 1962; however, processing and analysis of sediment data are not complete.

WORK PLAN FOR FY 1975

The runoff and sediment collection program will continue at plots and watersheds, and additional sediment-measuring facilities will be constructed at existing weirs.

Bedload and suspended sediment samplers will be used to determine rates of sediment movement at selected sites during flood events.

Sediment yield models will be investigated for applicability to Reynolds Creek Watershed conditions.

REPORTS AND PUBLICATIONS

Johnson, Clifton W., and Robin P. McArthur. 1973

Winter storm and flood analysis, Northwest Interior. Proceedings Hydraul. Div. Spec. Conf., Am. Soc. of Civil Engin., Bozeman, MT.

TABLE 1.--Descriptions of runoff-erosion plots and microwatersheds, Reynolds Creek Watershed, 1973. (See Figure 1, Introduction, for locations.)

Plots	No.	Elevation	Vegetative Cover %	Litter %	Rock Cover %	Bare Ground %
Summit	49050	4200	8.6	3.0	51.1	37.3
Windy Point	68024	4200	13.7	7.4	52.7	26.2
Nancy	98197	4600	39.1	11.0	12.2	37.7
Nettleton	135029	5000	31.9	31.0	3.9	33.2
Upper Sheep	138023	6100	44.9	8.7	32.5	<u>1/</u> 13.9
Reynolds Mtn.	176024	6900	62.6	8.0	23.3	<u>1/</u> 6.1
<u>Microwatersheds</u>						
Flats	57096	3900	59.6	9.4	9.9	<u>1/</u> 21.1
Nancy	98097	4600	39.1	11.0	12.2	37.7

1/ 1972 Measurements

TABLE 2.--Precipitation and runoff at selected stations, Reynolds Creek Watershed, 1973 water year.

Month	Precipitation ^{1/}		Runoff			
	12-Year Average	1973 Water Year	Outlet Weir ^{2/}		Reynolds Mtn. ^{3/}	
			11-Year Average	1973 Water Year	11-Year Average	1973 Water Year
	(In)	(In)	(In)	(In)	(In)	(In)
Oct.	.91	.85	.02	.05	.14	.21
Nov.	1.25	1.24	.05	.08	.26	.26
Dec.	1.23	1.65	.21	.18	.45	.33
Jan.	1.42	.67	.51	.24	.39	.33
Feb.	.59	.29	.31	.13	.53	.19
Mar.	.66	.62	.45	.15	.68	.20
Apr.	1.04	3.22	.57	.51	2.93	2.90
May	.81	.16	.59	.39	9.97	7.83
June	1.85	.89	.30	.07	4.35	.75
July	.15	.30	.04	.03	.47	.14
Aug.	.76	.44	.02	.01	.10	.05
Sept.	.53	1.22	.01	.01	.09	.05
Water Year	11.20	11.55	3.08	1.85	20.36	13.24

^{1/} Reynolds Weather Station, 076059, Weather Service Standard Gage^{2/} Reynolds Creek Outlet Weir, Station 036068, Watershed Area 90 sq. mi., Weir Elevation 3600 ft.^{3/} Reynolds Mountain Watershed, Station 166076, Drainage Area 100 a., Weir Elevation 6600 ft.

WATERSHED MODELING

Title: Developing, testing and evaluating watershed models.

Personnel Involved:

<u>W. J. Rawls</u> , Hydrol.	Coordinate all modeling efforts and develop and field test watershed models.
C. L. Hanson, Agr. Engin.	Develop and field test watershed models.
G. R. Stephenson, Geologist	Coordinate field data and test subsurface flow models
J. F. Zuzel, Hydrol. Tech.	Develop and field test watershed models.

Date of Initiation: June 1973

Expected Termination Date: Continuing

INTRODUCTION

The rapid development of high-speed computers over the past decade has provided the impetus for significant advances in the development of models for synthesizing the hydrologic cycle. In the past few years, several notable contributions have appeared in the literature, such as Crawford and Linsley (1966); James (1970); Dawdy and O'Donnel (1965); Holtan and Lopez (1971); Sittner, Schauss, and Monro (1968); and TVA (1972). The models consist of mathematical expressions that define relationships and interactions among components of the hydrologic cycle. These models are operated with precipitation as input, and the model parameters are calibrated to achieve an acceptable fit of simulated streamflow to observed streamflow. Different model parameter values are capable of yielding comparable simulations because many of the hydrologic processes are interrelated. Also, the various components may interact within the model, causing the parameters to compensate for each other and produce similar predictions. When such conditions exist, there is no positive verification that the mathematical expressions are a correct representation of the various hydrologic processes. To develop better models, the important components need to be isolated and studied.

Objectives:

1. To make a comprehensive review of the existing watershed models.

2. To calibrate the most promising models, using Reynolds Creek Watershed data.
3. To test the sensitivity of the data inputs to the various models.
4. To test the sensitivity of the various hydrologic components.
5. To improve the representation of the hydrologic components found most important for Reynolds Creek data.
6. To use the models to study the influence of land use and conservation practices on the hydrologic response of study watersheds.
7. To apply the models to ungaged watersheds in the Northwest.

PROGRESS

The primary effort at the Northwest Watershed Research Center has been directed toward studying the individual components of the hydrologic cycle. Now, two types of hydrologic models are being studied to determine the effect of each component. First, the distributed models, which chronologically route flows vertically and horizontally through the watershed; and second, the lumped models, which consider the watershed as a unit of hydrologic response. A comprehensive review of existing distributed watershed models applicable to the Northwest is in progress. When this review is completed, the models will be evaluated according to their applicability to answer management problems. During the past year two lumped models and one distributed model have been developed and/or tested. The following is a description of the models.

Long-Term Snowmelt-Runoff Model

A long-term snow-storage runoff-volume forecast model was developed using the equation:

$$y = a + b_1x_1 + b_2x_2 + \dots b_nx_n$$

where,

y = March-July runoff

a = fitting coefficient

$x_1 \dots x_n$ = peak snow course accumulation at each snow course

$b_1 \dots b_n$ = coefficient for each snow course

In the forecast model each "b" coefficient would be realistic and hydrologically sound if it represented a percentage of the total drainage area. It can then be seen that the terms $b_1x_1 \dots b_nx_n$ in the forecast equation are analogous to a weighted average scheme and can be expressed as:

$$y = a + \sum_{i=1}^n (b_i)(x_i)$$

The hydrologic significance of b_i can be maintained by the additional requirements of

$$b_i \geq 0 \text{ and } \sum_{i=1}^n b_i \leq 1$$

provided that runoff and snow water contents are expressed in the same units, such as centimeters or inches. The basis for this reasoning is that the snow water content at a snow course is considered to be a discrete sample of snow water content associated with an area within a drainage basin, and not simply an index of runoff volume. These assumptions put the forecast equation on a sound hydrologic basis since snow water contents are now expressed as depth-area functions representing the average snow water storage and can be related directly to runoff volume for any forecast period.

An optimization technique that minimizes the error of y for a forecast period by searching for the optimum combination of "b" coefficients and the fitting coefficient "a" was used to calibrate the model to data.

The forecast procedure was used to generate forecast equations for three drainage basins located in Southwest Idaho: Tollgate drainage (54 km²) of the Reynolds Creek Watershed, the Middle Fork of the Boise River (2150 km²), and the entire Boise River above Boise, Idaho (7000 km²). The average error for all forecast periods is 10 percent for the three watersheds. Comparisons with the accuracy of published forecasts for these forecast periods may be invalid due to the use of different parameters, but it does appear that the proposed method, using snow course data only, produces more accurate forecasts.

Short-Term Snowmelt-Runoff Model

A short-term snowmelt-runoff model was developed at the Northwest Watershed Research Center (Cox and Zuzel, 1973). The model is basically a lag cross correlation model for which regression coefficients are calculated. The required inputs to the model are daily snowmelt from a snowmelt collector and daily streamflow.

The daily forecasts produced by the model are based on the calculated regression coefficients. The generation of unrealistically high correlation coefficients, caused by the accumulation of input parameters, is not considered to seriously affect the accuracy of the model.

This model has been tested on the Tollgate drainage of Reynolds Creek (54 km²), as well as larger drainage areas, including the South Fork of the Boise River (1,022 km²) and the Middle Fork of the Boise River (1,335 km²).

Model output is mean daily streamflow 24 hours in advance. Errors in daily forecasts have been about 10 percent, and results indicate that forecasts up to 3 days in advance can be made with reasonable accuracy.

Also, if the total water content remaining in the snowpack is used as input, extended volume forecasts can be made. This procedure has been tested and incorporated into the model.

Subsurface Flow Model

An example of a distributed model already tested is the transient, saturated-unsaturated, subsurface flow model developed by Freeze, 1972. The model was tested in simulating the subsurface flow regime from snowmelt in a two-dimensional, vertical cross section on an instrumented slope in a small, upstream source area of Reynolds Creek. Field measurements show that the mechanism of streamflow generation is subsurface delivery of melt water over limited distances through shallow, high-permeability, low-porosity formations of altered and fractured basalt. Overland flow is seldom observed on these slopes during snowmelt. Figure 1 shows the location of the study site, and Figure 2 shows the hillslope topography, geology, and instrumentation.

Output from the model gives plots of the pressure head, total head, and moisture content fields at any time step. The transient position of the water table and the development of the seepage face at the channel are determined from the pressure head field. Outflow through the seepage face is calculated from the head field.

A simulation of the subsurface flow on this instrumented slope was run over a 100-day period during the 1971 spring snowmelt season. Figure 3 shows the comparison between the measured and simulated system for this run. The water levels in three piezometers and the estimated subsurface outflow to the stream, shown in Figure 3, are the comparative checks between field measurements and model output. The graphic comparisons are probably representative of the type of results that can be expected from the application of complex theoretical models to complex field situations under the constraints created by data limitations and the resulting uncertainties in the calibration procedures.

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- Sittner, W. T., C. E. Schauss, and J. C. Monro 1968
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SIGNIFICANT FINDINGS

Long-term and short-term snowmelt forecast models were developed and successfully tested for a number of watersheds.

A two-dimensional, transient model was used to simulate subsurface flow from a melting snowdrift to a stream channel. The results, when compared to the actual 1971 snowmelt season field measurements, were satisfactory.

WORK PLAN FOR FY 1975

Snowmelt forecast models will be further refined. Also, the comprehensive review of existing watershed models will be completed and the most promising will be calibrated to Reynolds Creek data.

The subsurface flow model will be tested using the 1972 snowmelt data from Upper Sheep Creek.

REPORTS AND PUBLICATIONS

Stephenson, G. R., and Freeze, R. A. 1974
Mathematical Simulation of Subsurface Flow Contribution to
Snowmelt Runoff, Reynolds Creek Watershed, Idaho. Water Resources
Res. In Press.

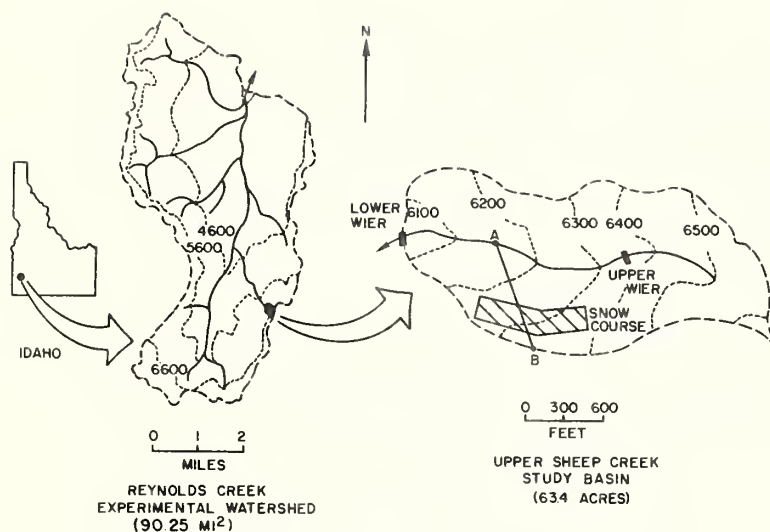


Figure 1. Location maps, Upper Sheep Creek study basin, Idaho.

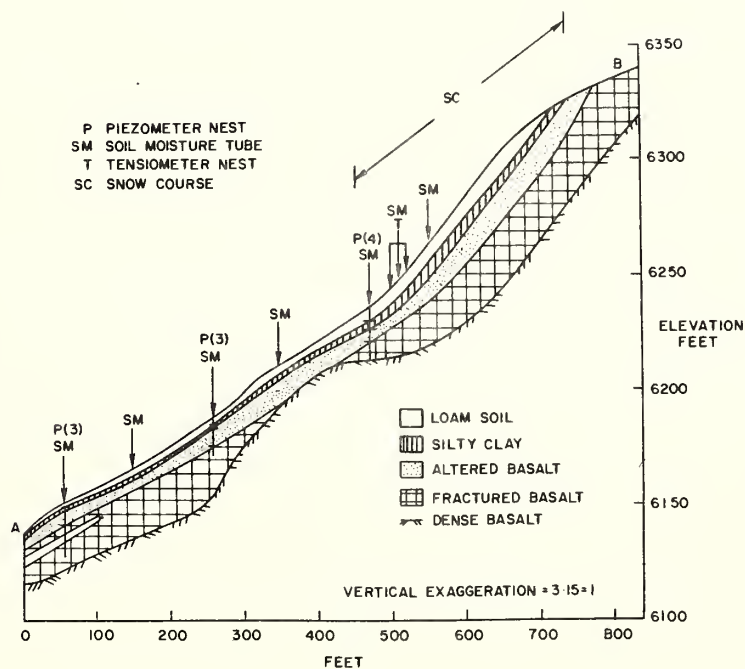


Figure 2. Geologic cross section and guide to instrumentation along section AB in Figure 1.

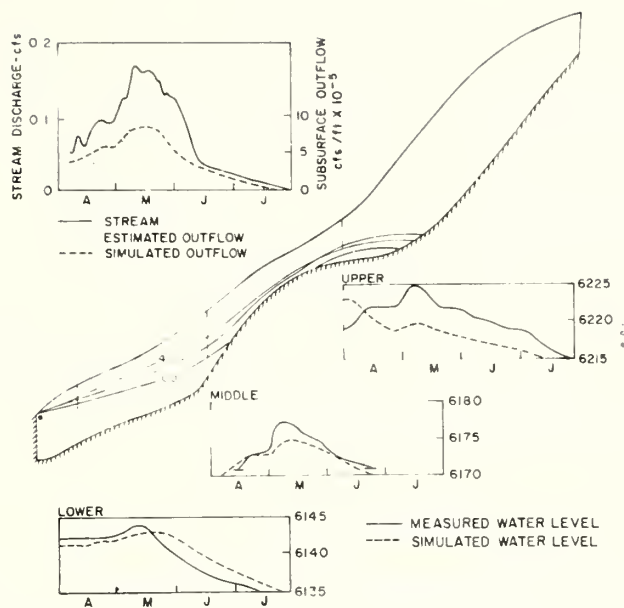


Figure 3. Calibrated transient flow system for the period April 5 to July 13, 1971.

FRAIL LAND STUDIES

Title: Hydrology of frail land watersheds

Personnel Involved:

C. W. Johnson, Supvy. Hydrol. Engin.	Perform water balance and any other analysis needed.
W. J. Rawls, Hydrologist	Perform water balance and other analysis needed.

Date of Initiation: October 1968

Expected Termination Date: Field Work - October 1973

Interpretation and Summary - July 1974

INTRODUCTION

Proper management of watersheds for multiple use and protection requires a complete knowledge of the water balance with independent assessments of the water balance components. In order to determine the individual components for frail lands, a study of the hydrology of two watersheds, Rabbit Creek and Little Rabbit Creek, adjoining the Reynolds Creek Experimental Watershed, was initiated in 1968. A complete description of the watersheds and instrumentation was included in the 1968-69 water-year report.

Objective:

To determine the water balance of two frail land watersheds in the Northwest.

PROGRESS

Operation of five dual rain gage installations, two runoff stations, and 10 soil moisture measuring sites were continued through October 1, 1973, to complete the 5-year study period. After October 1, 1973, all instrumentation was removed from the watersheds. The data for the 5-year period of study (1968-1973) has been error checked and processed. The termination report on the Rabbit Creek watersheds will be submitted to BLM about June 30, 1974, and will include:

Summaries and Evaluation:

1. Evaluation and summary of the data collected.
2. Data and analysis of all storms causing runoff greater than 0.3 cfs.
3. Frequency and intensity analysis of the precipitation data.
4. A water balance for each watershed on a water-year basis.

SIGNIFICANT FINDINGS

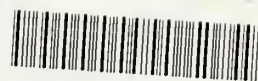
None.

WORK PLAN FOR FY 1975

None.

REPORTS AND PUBLICATIONS

None.



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